



Type B-3 100% Submission Specifications – Volume 2

Corrosion Control Facility
Texas Air National Guard 149th FW



NGB Contract: W9133L16D0005
Task Order: W912L1-19-F-0013
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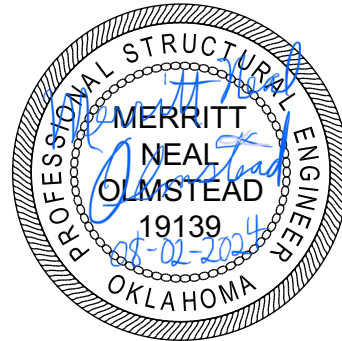


Construct Corrosion Control Facility
PN: KELL169014
Joint Base San Antonio, Kelly Annex, TX

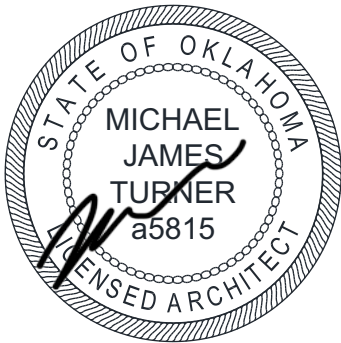


Lindsay Hausman

Civil



Structural



Architectural



Fire Protection



Mechanical



Electrical

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WET PIPE SPRINKLER SYSTEMS, FIRE PROTECTION
08/20

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B16.1	(2022) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250
ASME B16.3	(2021) Malleable Iron Threaded Fittings, Classes 150 and 300
ASME B16.4	(2021) Gray Iron Threaded Fittings; Classes 125 and 250
ASME B16.21	(2021) Nonmetallic Flat Gaskets for Pipe Flanges

AMERICAN SOCIETY OF SANITARY ENGINEERING (ASSE)

ASSE 1013	(2021) Performance Requirements for Reduced Pressure Principle Backflow Prevention Assemblies
ASSE 1015	(2011) Performance Requirements for Double Check Backflow Prevention Assemblies and Double Check Fire Protection Backflow Prevention Assemblies - (ANSI approved 2010)

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C104/A21.4	(2022) Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
AWWA C110/A21.10	(2021) Ductile-Iron and Gray-Iron Fittings
AWWA C111/A21.11	(2017) Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
AWWA C203	(2020) Coal-Tar Protective Coatings and Linings for Steel Water Pipelines - Enamel and Tape - Hot-Applied
AWWA M14	(4th Ed) Backflow Prevention and Cross-Connection Control; Recommended Practices

ASTM INTERNATIONAL (ASTM)

ASTM A47/A47M	(1999; R 2022; E 2022) Standard Specification for Ferritic Malleable Iron Castings
ASTM A53/A53M	(2022) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A135/A135M	(2009; R2014) Standard Specification for Electric-Resistance-Welded Steel Pipe
ASTM A153/A153M	(2023) Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A183	(2014; R 2020) Standard Specification for Carbon Steel Track Bolts and Nuts
ASTM A536	(1984; R 2019; E 2019) Standard Specification for Ductile Iron Castings

FM GLOBAL (FM)

FM APP GUIDE	(updated on-line) Approval Guide http://www.approvalguide.com/
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INTELLIGENCE COMMUNITY STANDARD (ICS)

ICS 705-1	(2010) Physical and Technical Security Standard for Sensitive Compartmented Information Facilities
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MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS
INDUSTRY (MSS)

MSS SP-71	(2018) Gray Iron Swing Check Valves, Flanged and Threaded Ends
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NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 13	(2022) Standard for the Installation of Sprinkler Systems
NFPA 20	(2022;TIA 21-1; TIA 21-2) Standard for the Installation of Stationary Pumps for Fire Protection
NFPA 24	(2022) Standard for the Installation of Private Fire Service Mains and Their Appurtenances
NFPA 101	(2021; TIA 21-1) Life Safety Code
NFPA 291	(2022) Recommended Practice for Fire Flow Testing and Marking of Hydrants

NATIONAL INSTITUTE FOR CERTIFICATION IN ENGINEERING TECHNOLOGIES
(NICET)

NICET 1014-7 (2012) Program Detail Manual for
Certification in the Field of Fire
Protection Engineering Technology (Field
Code 003) Subfield of Automatic Sprinkler
System Layout

UNDERWRITERS LABORATORIES (UL)

UL 199 (2020) UL Standard for Safety Automatic
Sprinklers for Fire-Protection Service

UL 262 (2004; Reprint Oct 2011) Gate Valves for
Fire-Protection Service

UL 312 (2010; Reprint Mar 2018) UL Standard for
Safety Check Valves for Fire-Protection
Service

UL 789 (2004; Reprint May 2017) UL Standard for
Safety Indicator Posts for Fire-Protection
Service

UL Fire Prot Dir (2012) Fire Protection Equipment Directory

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-600-01 (2016; with Change 6, 2021) Fire
Protection Engineering for Facilities

1.2 SYSTEM DESCRIPTION

Provide wet pipe sprinkler system(s) in areas indicated on the drawings.
The system must meet the requirements of NFPA 13 and UFC 3-600-01. Pipe
sizes must be determined by hydraulic calculations.

1.2.1 Hydraulic Design

1.2.1.1 Basis for Calculations

A waterflow test was performed on the potable water supply on 8/2/2017
and resulted in a static pressure of 70 psi with a residual pressure of 22
psi while flowing 2555 gpm. Perform a new fire hydrant flow test prior to
shop drawing submittal in accordance with NFPA 291. Results must include
hydrant elevations relative to the building and hydrant number/identifiers
for the tested hydrants, including which were flowed, which had a gauge.
This information must be presented in a tabular form if multiple hydrants
were flowed. The results must be included with the hydraulic
calculations. Hydraulic calculations must be based on contractor performed
flow test noted in this paragraph with 15 psi margin of safety. Hydraulic
calculations must be based upon the Hazen-Williams formula with a "C"
value noted in NFPA 13 for piping, and C=100 for existing underground
piping.

1.2.1.2 Hydraulic Calculations

- a. Water supply curves and system requirements must be plotted on

semi-logarithmic graph ($N^{1.85}$) paper so as to present a summary of the complete hydraulic calculation.

- b. Provide a summary sheet listing sprinklers in the design area and their respective hydraulic reference points, elevations, minimum discharge pressures and minimum flows. Elevations of hydraulic reference points (nodes) must be indicated.
- c. Documentation must identify each pipe individually and the nodes connected thereto. Indicate the diameter, length, flow, velocity, friction loss, number and type fittings, total friction loss in the pipe, equivalent pipe length and Hazen-Williams coefficient for each pipe.
- d. All calculations must include the backflow preventer manufacturer's stated friction loss at the design flow or 8 psi for double check backflow preventer, whichever is greater.
- e. All calculations must be performed back to the actual location of the flow test, taking into account the direction of flow in the service main at the test location.
- f. For gridded systems, calculations must show peaking of demand area friction loss to verify that the hydraulically most demanding area is being used. A flow diagram indicating the quantity and direction of flows must be included.

1.2.1.3 Design Criteria

Hydraulically design the system to discharge a minimum density in accordance with UFC 3-600-01, Table 9-3, for the Hazard Classification indicated on the drawings. Hazard classification shall meet or exceed that required by NFPA 13. Hydraulic calculations must be in accordance with the Area/Density Method of NFPA 13. Add an allowance of 500 gpm at the point of connection for exterior hose streams since the hydrants are on the potable water supply. Include a 15 psi margin of safety.

1.2.2 Sprinkler Coverage

Sprinklers must be uniformly spaced on branch lines. Provide coverage throughout 100 percent of the area noted on the Contract drawings. This includes, but is not limited to, telephone rooms, electrical equipment rooms (regardless of the fire resistance rating of the enclosure), boiler rooms, switchgear rooms, transformer rooms, attached electrical vaults and other electrical and mechanical spaces. Coverage per sprinkler must be in accordance with NFPA 13. Provide sprinklers below all obstructions in accordance with NFPA 13. Exceptions are as follows:

- a. Sprinklers may be omitted from small rooms which are exempted for specific occupancies in accordance with NFPA 101.

1.2.3 Qualified Fire Protection Engineer (QFPE)

An individual who is a licensed professional engineer (P.E.) who has passed the fire protection engineering written examination administered by the National Council of Examiners for Engineering and Surveying (NCEES) and has relevant fire protection engineering experience, including three projects similar to this one which have been in satisfactory use for at least six months. Services of the QFPE must include:

- a. Reviewing SD-02, SD-03, and SD-05 submittal packages and preliminary test procedures and reports for completeness and compliance with the provisions of this specification. Working (shop) drawings and calculations must be prepared by, or prepared under the immediate supervision of, the QFPE. The QFPE must affix their professional engineering seal or submittal review stamp with signature to the shop drawings, calculations, and material data sheets, indicating approval prior to submitting the shop drawings to the DFPE.
- b. Provide a letter documenting that the SD-02, SD-03, and SD-05 submittal package has been reviewed and noting all outstanding comments.
- c. Performing in-progress construction surveillance prior to installation of ceilings (rough-in inspection).
- d. Reviewing SD-06 test plans and procedures and test reports for completeness and compliance with the provisions of this specification. The QFPE must affix their review stamp with signature to the test plans and reports indicating approval before submitting to the DFPE.
- e. Witnessing pre-Government and final Government functional performance testing and performing a final installation review.
- f. Signing applicable certificates under SD-07.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. Partial submittals and submittals not fully complying with NFPA 13 and this specification section must be returned disapproved without review. SD-02, SD-03 and SD-05 must be submitted simultaneously.

Shop drawings (SD-02), product data (SD-03) and calculations (SD-05) must be prepared by the designer and combined and submitted as one complete package, with the SD-03 product data submitted under separate transmittal. The QFPE must review the SD-02/SD-03/SD-05 submittal package for completeness and compliance with the Contract provisions prior to submission to the Government. The QFPE must provide a Letter of Confirmation that they have reviewed the submittal package for compliance with the contract provisions. This letter must include their professional engineer stamp and signature. Partial submittals and submittals not reviewed by the QFPE will be returned disapproved without review.

Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Qualified Fire Protection Engineer (QFPE); G

Sprinkler System Designer; G

Sprinkler System Installer; G

SD-02 Shop Drawings

Shop Drawing; G

SD-03 Product Data

Pipe; G

Fittings; G

Valves, including gate, check, butterfly, and globe; G

Riser Check Valves; G

Relief Valves; G

Sprinklers ; G

Pipe Hangers and Supports ; G

Sprinkler Alarm Switch; G

Valve Supervisory (Tamper) Switch; G

Fire Department Connection; G

Backflow Prevention Assembly; G

Air Vent; G

Hose Valve; G

Nameplates; G

Test Procedures

SD-05 Design Data

Hydraulic Calculations; G

SD-06 Test Reports

Preliminary Test Procedures; G

Final Test Procedures; G

Preliminary Test Report; G

Final Test Report; G

SD-07 Certificates

Verification of Compliant Installation; G

Request for Government Final Test; G

SD-10 Operation and Maintenance Data

Posted Operating and Maintenance (O&M) Instructions; G

Operating and Maintenance (O&M) Instructions; G

Spare Parts Data; G

SD-11 Closeout Submittals

As-built drawings

1.4 QUALITY ASSURANCE

1.4.1 Preconstruction Submittals

Within 36 days of contract award but no less than 14 days prior to commencing work on site, the prime Contractor must submit the SD-01 Preconstruction Submittals with documentation of qualifications for review and approval. SD-02, SD-03 and SD-05 submittals received prior to the review and approval of the qualifications will be returned Disapproved Without Review.

1.4.1.1 Shop Drawing

Three paper copies and one digital copy in a format acceptable to the Contracting Officer of the shop drawings, no later than 28 days prior to the start of system installation. Working drawings conforming to the requirements prescribed in NFPA 13 and must be no smaller than the Contract Drawings. Each set of drawings must include the following:

1. A descriptive index with drawings listed in sequence by number. A legend sheet identifying device symbols, nomenclature, and conventions used in the package.
2. Floor plans drawn to a scale not less than 1/8-inch equals 1-foot clearly showing locations of devices, equipment, risers, and other details required to clearly describe the proposed arrangement. Text height shall be minimum 1/10".
3. Actual center-to-center dimensions between sprinklers on branch lines and between branch lines; from end sprinklers to adjacent walls; from walls to branch lines; from sprinkler feed mains, cross mains and branch lines to finished floor and roof or ceiling. A detail must show the dimension from the sprinkler and sprinkler deflector to the ceiling in finished areas.
4. Longitudinal and transverse building sections showing typical branch line and cross main pipe routing, elevation of each typical sprinkler above finished floor and elevation of "cloud" or false ceilings in relation to the building ceilings.
5. Plan and elevation views which establish that the equipment will fit the allotted spaces with clearance for installation and maintenance.
6. Enlarged riser layout plans and section drawings drawn to a scale of not less than 1/2-inch equals 1-foot to show details of each system component, clearances between each other and from other equipment and construction in the room.
7. Details of each type of riser assembly, pipe hanger, and restraint of

underground water main at point-of-entry into the building, and electrical devices and interconnecting wiring. The dimension from the edge of vertical piping to the nearest adjacent wall(s) must be indicated on the drawings when vertical piping is located in stairs or other portions of the means of egress.

8. Details of each type of pipe hanger, force protection bracing/restraint and related components.

1.4.1.2 Product Data

Three paper and one digital copy of annotated catalog data to show the specific model, type, and size of each item. Catalog cuts must also indicate the NRTL listing. The data must be highlighted to show model, size, options, and other pertinent information, that are intended for consideration. Data must be adequate to demonstrate compliance with all contract requirements. Product data for all equipment must be combined into a single submittal and submitted at the same time as the shop drawings and calculations submittal.

1.4.1.3 Hydraulic Calculations

Calculations must be as outlined in NFPA 13 except that calculations must be performed by computer using software intended specifically for fire protection system design using the design data shown on the drawings. Calculations must include isometric diagram indicating hydraulic nodes and pipe segments.

1.4.1.4 Operating and Maintenance (O&M) Instructions

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA as supplemented and modified by this specification section.

Provide six paper manuals with tabs and bookmarks corresponding to the table of contents and one pdf version on electronic media. The manuals must include the manufacturer's name, model number, parts list, list of parts and tools that should be kept in stock by the owner for routine maintenance, troubleshooting guide, and recommended service organization (including address and telephone number) for each item of equipment.

Submit spare parts data for each different item of material and equipment specified. The data must include a complete list of parts and supplies, and a list of parts recommended by the manufacturer to be replaced after 1-year and 3 years of service. Include a list of special tools and test equipment required for maintenance and testing of the products supplied.

1.4.1.4.1 Posted Operating and Maintenance (O&M) Instructions

Provide Posted O&M Instructions, in color with professionally prepared graphics, 15" x 21" or larger, framed in heavy gauge extruded metal frames, mounted under glass, water/weatherproof. Permanently mount in a reserved clear wall area as shown on the shop drawings, near FACU and/or sprinkler riser. Include comprehensive schematics for sprinkler and fire alarm systems, facility floor plans showing location of all fire equipment and devices with coordinated identification. Include fire rated walls, fire dampers, fire alarm riser diagram, I/O matrix, point list, and all components. Include valve charts, equipment schedule and wiring diagrams and schematics.

1.4.2 Qualifications

1.4.2.1 Sprinkler System Designer

The sprinkler system designer must be certified as a Level IV Technician by National Institute for Certification in Engineering Technologies (NICET) in the Water-Based Systems Layout subfield of Fire Protection Engineering Technology in accordance with NICET 1014-7.

1.4.2.2 Sprinkler System Installer

The sprinkler system installer must be regularly engaged in the installation of the type and complexity of system specified in the contract documents, and must have served in a similar capacity for at least three systems that have performed in the manner intended for a period of not less than 6 months.

1.4.3 Regulatory Requirements

Equipment and material must be listed or approved. Listed or approved, as used in this Section, means listed, labeled or approved by a Nationally Recognized Testing Laboratory (NRTL) such as UL Fire Prot Dir or FM APP GUIDE. The omission of these terms under the description of an item or equipment described must not be construed as waiving this requirement. All listings or approvals by testing laboratories must be from an existing ANSI or UL published standard. The recommended practices stated in the manufacturer's literature or documentation are mandatory requirements.

1.5 DELIVERY, STORAGE, AND HANDLING

Protect all equipment delivered and placed in storage from the weather, excessive humidity and temperature variations, dirt and dust, or other contaminants. All pipes must be either capped or plugged until installed.

1.6 EXTRA MATERIALS

Spare sprinklers and wrench(es) must be provided as spare parts in accordance with NFPA 13.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

2.1.1 Standard Products

Provide materials, equipment, and devices listed for fire protection service when so required by NFPA 13 or this specification. Select material from one manufacturer, where possible, and not a combination of manufacturers, for a classification of material. Material and equipment must be standard products of a manufacturer regularly engaged in the manufacture of the products for at least 2 years prior to bid.

2.1.2 Nameplates

Major components of equipment must have the manufacturer's name, address, type or style, model or serial number, catalog number, date of installation, installing Contractor's name and address, and the contract number provided on a new name plate permanently affixed to the item or

equipment. Nameplates must be etched metal or plastic, permanently attached by screws to control units, panels or adjacent walls.

2.1.3 Identification and Marking

Pipe and fitting markings must include name or identifying symbol of manufacturer and nominal size. Pipe must be marked with ASTM designation. Valves and equipment markings must have name or identifying symbol of manufacturer, specific model number, nominal size, name of device, arrow indicating direction of flow, and position of installation (horizontal or vertical), except if valve can be installed in either position. Markings must be included on the body casting or on an etched or stamped metal nameplate permanently on the valve or cover plate.

2.1.4 Pressure Ratings

Valves, fittings, couplings, alarm switches, and similar devices must be rated for the maximum working pressures that can be experienced in the system, but in no case less than 175 psi.

2.2 UNDERGROUND PIPING COMPONENTS

2.2.1 Pipe

Pipe must comply with NFPA 24. Piping more than 5 feet outside the building walls must comply with NFPA 24, UFC 3-600-01, Specifications Division 33 and the Civil drawings. A continuous section of welded stainless steel fire water service piping from a point outside the building perimeter to a flanged fitting at 12 inches above the finished floor within the building is required.

2.2.2 Fittings and Gaskets

Fittings must be ductile-iron conforming to AWWA C110/A21.10 with cement mortar lining conforming to AWWA C104/A21.4. Gaskets must be suitable in design and size for the pipe with which such gaskets are to be used. Gaskets for ductile-iron pipe joints must conform to AWWA C111/A21.11.

2.2.3 Gate Valve and Indicator Posts

Installation must comply with NFPA 24. Gate valves for use with indicator post must conform to UL 262. Indicator posts must conform to UL 789 and shall be provided with supervisory switches monitored by the fire alarm system. Provide each indicator post with one coat of primer and two coats of red enamel paint.

2.2.4 Valve Boxes

Except where indicator posts are provided, for each buried valve, provide a cast-iron, ductile-iron, or plastic valve box of a suitable size. Plastic boxes must be constructed of acrylonitrile-butadiene-styrene (ABS) or inorganic fiber-reinforced black polyolefin. Provide cast-iron, ductile-iron, or plastic cover for valve box with the word "WATER" cast on the cover. The minimum box shaft diameter must be 5.25 inches. Coat cast-iron and ductile-iron boxes with bituminous paint applied to a minimum dry-film thickness of 10 mils.

2.2.5 Buried Utility Warning and Identification Tape

Provide detectable aluminum foil plastic backed tape or detectable magnetic plastic tape manufactured specifically for warning and identification of buried piping. Tape must be detectable by an electronic detection instrument. Provide tape, 3 inches minimum width, color coded for the utility involved with warning and identification imprinted in bold block letters continuously and repeatedly over the entire tape length. Warning and identification must read "CAUTION BURIED WATER PIPING BELOW" or similar wording. Use permanent code and letter coloring unaffected by moisture and other substances contained in trench backfill material.

2.3 ABOVEGROUND PIPING COMPONENTS

2.3.1 Steel Piping Components

2.3.1.1 Steel Pipe

Except as modified herein, pipe must be black steel as permitted by NFPA 13 and conform to the applicable provisions of ASTM A53/A53M, ASTM A135/A135M or ASTM A153/A153M. Steel pipe must be minimum Schedule 40.

2.3.1.2 Fittings

Fittings must be shop welded, threaded, or grooved-end type. Threaded fittings must be cast-iron conforming to ASME B16.4, malleable-iron conforming to ASME B16.3 or ductile-iron conforming to ASTM A536. Plain-end fittings with mechanical couplings, fittings that use steel gripping devices to bite into the pipe, steel press fittings and field welded fittings are not permitted. Fittings, mechanical couplings, and rubber gaskets must be supplied by the same manufacturer. Threaded fittings must use Teflon tape or manufacturer's approved joint compound. Saddle tees using rubber gasketed fittings are prohibited. Reducing couplings are not permitted.

2.3.1.3 Grooved Mechanical Joints and Fittings

Joints and fittings must be designed for not less than 175 psi service and the product of the same manufacturer. Field welded fittings must not be used. Fitting and coupling housing must be malleable-iron conforming to ASTM A47/A47M, Grade 32510; ductile-iron conforming to ASTM A536, Grade 65-45-12. Rubber gasketed grooved-end pipe and fittings with mechanical couplings are permitted in pipe sizes 2 inches and larger. Gasket must be the flush type that fills the entire cavity between the fitting and the pipe. Nuts and bolts must be heat-treated steel conforming to ASTM A183 and must be cadmium-plated or zinc-electroplated.

2.3.1.4 Flanges

Flanges must conform to NFPA 13 and ASME B16.1. Flange adapters are not permitted. Gaskets must be non-asbestos compressed material in accordance with ASME B16.21, 1/16-inch thick, and full face or self-centering flat ring type.

2.3.2 Flexible Sprinkler Hose

Braided flexible sprinkler hose is not permitted.

2.3.3 Pipe Hangers and Supports

Provide galvanized pipe hangers and supports in accordance with NFPA 13.

2.3.4 Valves

Provide valves of types approved for fire service. Valves must open by counterclockwise rotation.

2.3.4.1 Control Valve

Manually operated sprinkler control/gate valve must be outside stem and yoke (OS&Y) type or butterfly type as indicated on the drawings and must be listed.

2.3.4.2 Check Valves

Check valves must comply with UL 312. Check valves 4 inches and larger must be of the swing type, have a clear waterway and meet the requirements of MSS SP-71, for Type 3 or 4. Inspection plate must be provided on valves larger than 6 inches.

2.3.5 Riser Check Valves

Provide riser check valve, pressure gauges and main drain. Provide pressure relief valve, inspector's test, and other components as required for a fully operational system.

2.4 ALARM INITIATING AND SUPERVISORY DEVICES

2.4.1 Sprinkler Alarm Switch

Vane flow switch(es). Connection of switch must be by the fire alarm installer. Vane type alarm actuating devices must have mechanical diaphragm controlled retard device adjustable from 10 to 60 seconds and must instantly recycle. Flow switches for elevator power shunt must not have a retard feature.

2.4.2 Valve Supervisory (Tamper) Switch

Switch must be integral to the control valve or suitable for mounting to the type of control valve to be supervised open. The switch must be tamper resistant and contain SPDT (Form C) contacts arranged to transfer upon removal of the housing cover or closure of the valve of more than two rotations of the valve stem.

2.5 BACKFLOW PREVENTION ASSEMBLY

Double-check valve assembly backflow preventer complying with ASSE 1013, ASSE 1015 and AWWA M14. Each check valve must have a drain. Backflow prevention assemblies must have current "Certificate of Approval from the Foundation for Cross-Connection Control and Hydraulic Research, FCCCHR List" and be listed for fire protection use. Listing of the specific make, model, design, and size in the FCCCHR List is acceptable as the required documentation.

2.5.1 Backflow Preventer Test Connection

Test connection must consist of a series of listed hose valves with 2

1/2-inch National Standard male hose threads with cap and chain.

2.6 FIRE DEPARTMENT CONNECTION

Fire department connection must be 2.5" type with aluminum body, matching wall escutcheon lettered "Auto Spkr". The connection must be a 2.5" with cap and chain, turned down 30 degrees.

2.7 SPRINKLERS

Sprinklers must comply with UL 199 and NFPA 13. Sprinklers with internal O-rings are not acceptable. Sprinklers in high heat areas including attic spaces or in close proximity to unit heaters must have temperature classification in accordance with NFPA 13. Extended coverage sprinklers are permitted for loading docks, residential occupancies and high-piled storage applications only.

2.7.1 Pendent Sprinkler

Pendent sprinkler must be recessed quick-response type with minimum nominal K-factor of 5.6, 8.0, or 11.2, per UFC 3-600-01 Table 9-3. Pendent sprinklers must have a polished chrome finish. Assembly must include an integral escutcheon. Provide recessed pendants where ceilings are provided unless concealed sprinklers are indicated.

2.7.2 Upright Sprinkler

Upright sprinkler must be brass quick-response type and have a minimum nominal K-factor of 5.6, 8.0 or 11.2, per UFC 3-600-01. Select K-factor per Table 9-3.

2.7.3 Sidewall Sprinkler

Sidewall sprinkler must be the quick-response type. Sidewall sprinkler must have a minimum nominal K-factor of 5.6, 8.0 or 11.2, per UFC 3-600-01. Select K-factor per Table 9-3. Sidewall sprinkler must have a brass finish.

2.7.4 Concealed Sprinkler

Concealed sprinkler must be quick-response type and have a minimum nominal K-factor of 5.6 or 8.0 per UFC 3-600-01. Select K-factor per Table 9-3. Coverplate must be white unless noted otherwise on drawings.

2.8 ACCESSORIES

2.8.1 Sprinkler Cabinet

Provide spare sprinklers in accordance with NFPA 13 and must be placed in a suitable metal or plastic cabinet of sufficient size to accommodate all the spare sprinklers and wrenches in designated locations. Spare sprinklers must be representative of, and in proportion to, the number of each type and temperature rating of the sprinklers installed as required by NFPA 13. At least one wrench of each type required must be provided.

2.8.2 Pendent Sprinkler Escutcheon

Escutcheon must be one-piece metallic type with a depth of less than 3/4-inch and suitable for installation on pendent sprinklers. The

escutcheon must have a factory finish that matches the pendent sprinkler.

2.8.3 Pipe Escutcheon

Provide split hinge metal plates for piping entering walls, floors, and ceilings in exposed spaces. Provide polished stainless steel plates or chromium-plated finish on copper alloy plates in finished spaces. Provide paint finish on metal plates in unfinished spaces.

2.8.4 Sprinkler Guard

Listed guard must be a steel wire cage designed to encase the sprinkler and protect it from mechanical damage. Guards must be provided on sprinklers located in rooms with electrical or communication equipment and on sprinklers within 7 feet of the floor and where indicated on drawings or required by NFPA 13.

2.8.5 Relief Valve

Relief valves must be listed and installed at the riser in accordance with NFPA 13.

2.8.6 Air Vent

Air vents must be of the automatic type and piped to drain to the building exterior.

2.8.7 Identification Sign

Valve identification sign must be minimum 6 inches wide by 2 inches high with enamel baked finish on minimum 18 gage steel or 0.024-inch aluminum with red letters on a white background or white letters on red background. Wording of sign must include, but not be limited to "main drain", "auxiliary drain", "inspector's test", "alarm test", "alarm line", and similar wording as required to identify operational components. Where there is more than one sprinkler system, signage must include specific details as to the respective system.

2.8.8 Posted Operating and Maintenance (O&M) Instructions

O&M Manuals shall be completed, submitted and approved no later than 30 days prior to beneficial occupancy. Provide waterproof heavy metal extruded framed permanent posted O&M instructions under glass that are coordinated with and keyed to the O&M Manuals and that utilize the system and device identification and operations identifications. Instructions shall have professionally prepared graphics, printed on full sized sheets, in color. Posted instructions shall show, at a minimum:

- (a) Comprehensive schematic piping diagrams including water supply, and sprinkler systems.
- (b) Facility floor plans showing location of all fire equipment and devices with coordinated identification. Show items such as fire walls, fire barriers, fire dampers, etc.
- (c) System diagrams, including isometrics of special equipment such as fire risers and all appurtenances.
- (d) Valve charts.
- (e) Equipment schedule.
- (f) Wiring diagrams and schematics.

PART 3 EXECUTION

3.1 VERIFYING ACTUAL FIELD CONDITIONS

Before commencing work, examine all adjoining work on which the contractor's work that is dependent for perfect workmanship according to the intent of this specification section, and report to the Contracting Officer's Representative a condition that prevents performance of first class work. No "waiver of responsibility" for incomplete, inadequate or defective adjoining work will be considered unless notice has been filed before submittal of a proposal.

3.2 INSTALLATION

The installation must be in accordance with the applicable provisions of NFPA 13, NFPA 24, UFC 3-600-01, and publications referenced therein. Locate sprinklers in a consistent pattern with ceiling grid, lights, and air supply diffusers. Install sprinkler system over and under ducts, piping and platforms when such equipment can negatively affect or disrupt the sprinkler discharge pattern and coverage. Do not locate sprinkler piping below finished ceilings.

- a. Piping offsets, fittings, and other accessories required must be furnished to provide a complete installation and to eliminate interference with other construction.
- b. Wherever the contractor's work interconnects with work of other trades the Contractor must coordinate with other Contractors to ensure all Contractors have the information necessary so that they may properly install all necessary connections and equipment. Identify all work items needing access (dampers and similar equipment) that are concealed above hung ceilings by permanent color coded pins/tabs in the ceiling directly below the item.
- c. Provide required supports and hangers for piping, conduit, and equipment so that loading will not exceed allowable loadings of structure. Submittal of a bid must be a deemed representation that the contractor submitting such bid has ascertained allowable loadings and has included in his estimates the costs associated in furnishing required supports.

3.2.1 Waste Removal

At the conclusion of each day's work, clean up and stockpile on site all waste, debris, and trash which may have accumulated during the day as a result of work by the contractor and of his presence on the job. Sidewalks and streets adjoining the property must be kept broom clean and free of waste, debris, trash and obstructions caused by work of the contractor, which will affect the condition and safety of streets, walks, utilities, and property.

3.3 UNDERGROUND PIPING INSTALLATION

The fire protection water main must be laid, and joints anchored, in accordance with NFPA 24. Minimum depth of cover must be 6.5 feet or 12" below the frost line, whichever is deeper. The supply line must terminate inside the building with a flanged piece, the bottom of which must be set at 12" to 13" above the finished floor. A blind flange must be installed temporarily on top of the flanged piece to prevent the entrance of foreign

matter into the supply line. A concrete thrust block must be provided at the elbow where the pipe turns up toward the floor. In addition, joints must be anchored in accordance with NFPA 24. Buried steel components must be provided with a corrosion protective coating in accordance with AWWA C203. Piping more than 5 feet outside the building walls see the Civil drawings.

3.4 ABOVEGROUND PIPING INSTALLATION

The methods of fabrication and installation of the aboveground piping must fully comply with the requirements and recommended practices of NFPA 13 and this specification section.

3.4.1 Protection of Piping Against Earthquake Damage

Seismic restraint is not required for sprinkler piping.

3.4.2 Piping in Exposed Areas

Install exposed piping without diminishing exit access widths, corridors or equipment access. Exposed horizontal piping, including drain piping, must be installed to provide maximum headroom.

3.4.3 Piping in Finished Areas

In areas with suspended or dropped ceilings and in areas with concealed spaces above the ceiling, piping must be concealed above ceilings. Piping must be inspected, hydrostatically tested and approved before being concealed. Risers and similar vertical runs of piping in finished areas must be concealed.

3.4.4 Pendent Sprinklers

- a. Drop nipples to pendent sprinklers must consist of minimum 1-inch pipe with a reducing coupling into which the sprinkler must be threaded.
- b. Where sprinklers are installed below suspended or dropped ceilings, drop nipples must be cut such that sprinkler ceiling plates or escutcheons are of a uniform depth throughout the finished space. The outlet of the reducing coupling must not extend below the underside of the ceiling.
- c. Recessed pendent sprinklers must be installed such that the distance from the sprinkler deflector to the underside of the ceiling must not exceed the manufacturer's listed range and must be of uniform depth throughout the finished area.
- d. Pendent sprinklers in suspended ceilings must be located in the center of the tile (+/- 2 inches).
- e. Dry pendent sprinkler assemblies must be such that sprinkler ceiling plates or escutcheons are of the uniform depth throughout the finished space.
- f. Dry pendent sprinklers must be of the required length to permit the sprinkler to be threaded directly into a branch line tee.
- g. Where the maximum static or flowing pressure, whichever is greater at the sprinkler, applied other than through the fire department

connection, exceeds 100 psi and a branch line above the ceiling supplies sprinklers in a pendent position below the ceiling, the cumulative horizontal length of an unsupported armover to a sprinkler or sprinkler drop must not exceed 12 inches.

3.4.5 Upright Sprinklers

Riser nipples or "sprigs" to upright sprinklers must contain no fittings between the branch line tee and the reducing coupling at the sprinkler.

3.4.6 Pipe Joints

Pipe joints must conform to NFPA 13, except as modified herein. Not more than four threads must show after joint is made up. Welded joints will be permitted, only if welding operations are performed as required by NFPA 13 at the Contractor's fabrication shop, not at the project construction site. Flanged joints must be provided where indicated or required by NFPA 13. Grooved pipe and fittings must be prepared in accordance with the manufacturer's latest published specification according to pipe material, wall thickness and size. Grooved couplings, fittings and grooving tools must be products of the same manufacturer. The diameter of grooves made in the field must be measured using a "go/no-go" gauge, vernier or dial caliper, narrow-land micrometer, or other method specifically approved by the coupling manufacturer for the intended application. Groove width and dimension of groove from end of pipe must be measured and recorded for each change in grooving tool setup to verify compliance with coupling manufacturer's tolerances.

3.4.7 Reducers

Reductions in pipe sizes must be made with one-piece tapered reducing fittings.

3.4.8 Pipe Penetrations

- a. Cutting structural members for passage of pipes or for pipe-hanger fastenings will not be permitted. Pipes that must penetrate concrete or masonry walls or concrete floors must be core-drilled and provided with pipe sleeves. Each sleeve must be Schedule 40 galvanized steel, ductile-iron or cast-iron pipe and extend through its respective wall or floor and be cut flush with each wall surface. Sleeves must provide required clearance between the pipe and the sleeve per NFPA 13. The space between the sleeve and the pipe must be firmly packed with mineral wool insulation.
- b. Where pipes and sleeves penetrate fire walls, fire partitions, or floors, pipes/sleeves must be firestopped by the approved firestop installer per approved designs and firestop shop drawings, in accordance with Section 07 84 00 FIRESTOPPING.
- c. In penetrations that are not fire-rated or not a floor penetration, the space between the sleeve and the pipe must be sealed at both ends with plastic waterproof cement that will dry to a firm but pliable mass or with a mechanically adjustable segmented elastomer seal.d. All penetrations through the boundary of rooms/areas identified as Area a space area must meet ICS 705-1.
- e. All piping penetrations through STC-rated walls must be grounded to earth within 2" of wall with #4 wire on both sides of the wall.

3.4.9 Escutcheons

Escutcheons must be provided for pipe penetration in finished areas of ceilings, floors and walls. Escutcheons must be securely fastened to the pipe at surfaces through which piping passes.

3.4.10 Inspector's Test Connection

Unless otherwise indicated, the test connection must consist of 1-inch pipe connected at the riser as a combination test and drain valve; a fully accessible test valve located approximately 7 feet above the floor; a smooth bore brass outlet equivalent to the smallest orifice sprinkler used in the system; and a painted metal identification sign affixed to the valve with the words "Inspector's Test". All test connection piping must be inside of the building and penetrate the exterior wall at the location of the discharge orifice only. The discharge orifice must be located outside the building wall no more than 2 feet above finished grade, directed so as not to cause damage to adjacent construction or landscaping during full flow discharge, or to the sanitary sewer. Discharge to the exterior must not interfere with exiting from the facility. Water discharge or runoff must not cross the path of egress from the building. Do not discharge to the roof. Discharge to floor drains, janitor sinks or similar fixtures is not permitted.

Provide concrete splash blocks at all drain and inspector's test connection discharge locations if not discharging to a concrete surface. Splash blocks must be large enough to mitigate erosion and not become dislodged during a full flow of the drain. Ensure all discharged water drains away from the facility and does not cause property damage.

3.4.11 Backflow Preventer

Locate within the building.

Install backflow preventers so that the bottom of the assembly is a minimum of 6 inches above the finished floor/grade. Install horizontal backflow preventers so that the bottom of the assembly is no greater than 24 inches above the finished floor/grade. Install vertical backflow preventers so that the upper operating handwheel is no more than 6 feet above the finished floor/grade. Clearance around control valve handles must be minimum 6 inches above grade/finished floor and away from walls.

3.4.12 Drains

- a. Main drain piping must be provided to discharge at a safe point outside the building, no more than 2 feet above finished grade. Provide a concrete splash block at drain outlet. Discharge to the exterior must not interfere with exiting from the facility. Water discharge or runoff must not cross the path of egress from the building.
- b. Auxiliary drains must be provided as required by NFPA 13 and must be fully accessible. Maximum height of auxiliary drain valves is 7 feet AFF. Auxiliary drains are permitted to discharge to a floor drain if the drain is sized to accommodate full flow or 40 gpm, whichever is greater. Discharge to service sinks or similar plumbing fixtures is not permitted.

3.4.13 Installation of Fire Department Connection

Connection must be mounted on the exterior wall approximately 3 feet above finished grade adjacent to and on the sprinkler system side of the backflow preventer. The piping between the connection and the FDC check valve must be provided with an automatic drip in accordance with NFPA 13 and piped to drain to the outside.

3.4.14 Identification Signs

Signs must be affixed to each control valve, inspector test valve, main drain, auxiliary drain, test valve, and similar valves as appropriate or as required by NFPA 13. Main drain test results must be etched into main drain identification sign. Hydraulic design data must be etched into the nameplates and permanently affixed to each sprinkler riser as specified in NFPA 13. Provide labeling on the surfaces of all feed and cross mains to show the pipe function (e.g., "Sprinkler System", "Fire Department Connection", "Standpipe") and normal valve position (e.g. "Normally Open", "Normally Closed"). For pipe sizes 4-inch and larger provide white painted stenciled letters and arrows, a minimum of 2 inches in height and visible from at least two sides when viewed from the floor. For pipe sizes less than 4-inch, provide white painted stenciled letters and arrows, a minimum of 0.75-inch in height and visible from the floor.

3.5 ELECTRICAL

Except as modified herein, electric equipment and wiring must be in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Alarm signal wiring connected to the building fire alarm control system must be by the fire alarm installer.

3.6 PAINTING

Color code mark piping as specified in Section 09 90 00 PAINTS AND COATINGS. Piping in finished areas shall be painted to match surroundings. Piping above ceilings, in unfinished spaces and in Fire Protection Room shall be painted red.

3.7 FIELD QUALITY CONTROL

3.7.1 Test Procedures

Submit detailed test procedures, prepared and signed by the NICET Level IV Fire Sprinkler Technician or QFPE, and the representative of the installing company, and reviewed by the QFPE, 60 days prior to performing system tests. Detailed test procedures must list all components of the installed system. Test procedures must include sequence of testing, time estimate for each test, and sample test data forms. The test data forms must be in a check-off format (pass/fail with space to add applicable test data; similar to the forms in NFPA 13.) The test procedures and accompanying test data forms must be used for the pre-Government testing and the Government final testing. Refer to the PAT/FAT Checklist following Section 28 31 76 for additional information.

- a. Provide space to identify the date and time of each test. Provide space to identify the names and signatures of the individuals conducting and witnessing each test.

3.7.2 Pre-Government Testing

3.7.2.1 Verification of Compliant Installation

Conduct inspections and tests to ensure that equipment is functioning properly. Tests must meet the requirements of paragraph entitled "Minimum System Tests" and "System Acceptance" as noted in NFPA 13. The Contractor and QFPE must be in attendance at the pre-Government testing to make necessary adjustments. After inspection and testing is complete, provide a signed Verification of Compliant Installation letter by the QFPE that the installation is complete, compliant with the specification and fully operable. The letter must include the names and titles of the witnesses to the pre-Government tests. Provide all completion documentation as required by NFPA 13 and the Preliminary Test Report certificates noted below, tabbed and bookmarked per the Table of Contents.

- a. NFPA 13 Contractor's Material and Test Certificates for Aboveground Piping
- b. NFPA 13 Contractor's Material and Test Certificates for Underground Piping, including flushing plan per NFPA 20 and NFPA 24 and flushing report with photos of flushing, flushing apparatus and flushing flow measurement.

3.7.2.2 Request for Government Final Test

When the verification of compliant installation has been completed, submit a formal request for Government final test to the Designated Fire Protection Engineer (DFPE) and Contracting Officer's Designated Representative (COR). Government final testing will not be scheduled until the DFPE has received copies of the request for Government Final testing and Verification of Compliant Installation letter with all required documentation, certificates and Test Reports. Government final testing will not be performed until after the connections to the installation fire alarm reporting system have been completed and tested to confirm communications are fully functional. Submit request for test at least 30 calendar days prior to the requested test date.

3.7.3 Correction of Deficiencies

If equipment was found to be defective or non-compliant with contract requirements, perform corrective actions and repeat the tests. Tests must be conducted and repeated if necessary until the system has been demonstrated to comply with all contract requirements.

3.7.4 Government Final Tests

The tests must be performed in accordance with the approved Final Test Procedures in the presence of the DFPE. Furnish instruments and personnel required for the tests. The following must be provided at the job site for Government Final Testing:

- a. The manufacturer's technical representative.
- b. The contractor's Qualified Fire Protection Engineer (QFPE).
- c. Marked-up red line drawings of the system as actually installed.

Government Final Tests will be witnessed by the Designated Fire Protection

Engineer, Contracting Officer, and Qualified Fire Protection Engineer (QFPE). At this time, all required tests noted in the paragraph "Minimum System Tests" must be repeated.

3.8 MINIMUM SYSTEM TESTS

The system, including the underground water mains, and the aboveground piping and system components, must be tested to ensure that equipment and components function as intended. The underground and aboveground interior piping systems and attached appurtenances subjected to system working pressure must be tested in accordance with NFPA 13, NFPA 20 and NFPA 24.

3.8.1 Underground Piping

3.8.1.1 Flushing

Underground piping must be flushed at a minimum of 15 fps or 150% of pump rated capacity, whichever is greater, without the use of the fire pump, in accordance with NFPA 24 and NFPA 20. Comply with state and local requirements regarding discharge of flushing water. Include flushing plan with preliminary test plan. Show flushing apparatus and how flow will be measured.

3.8.1.2 Hydrostatic Test

New underground piping must be hydrostatically tested in accordance with NFPA 24.

3.8.2 Aboveground Piping

3.8.2.1 Hydrostatic Test

Aboveground piping must be hydrostatically tested in accordance with NFPA 13. There must be no drop in gauge pressure or visible leakage when the system is subjected to the hydrostatic test. The test pressure must be read from a gauge located at the low elevation point of the system or portion being tested.

3.8.2.2 Backflow Prevention Assembly Forward Flow Test

Each backflow prevention assembly must be tested at system flow demand, including all applicable hose streams, as specified in NFPA 13. The Contractor must provide all equipment and instruments necessary to conduct a complete forward flow test, including 2.5-inch diameter hoses, playpipe nozzles or flow diffusers, calibrated pressure gauges, and pitot tube gauge. The Contractor must provide all necessary supports to safely secure hoses and nozzles during the test. At the system demand flow, the pressure readings and pressure drop (friction loss) across the assembly must be recorded. A metal placard must be provided on the backflow prevention assembly that lists the pressure readings both upstream and downstream of the assembly, total pressure drop, and the system test flow rate determined during the preliminary testing. The pressure drop must be compared to the manufacturer's data and the readings observed during the final inspections and tests.

3.8.3 Main Drain Flow Test

Following flushing of the underground piping, a main drain test must be made to verify the adequacy of the water supply. Static and residual

pressures must be recorded on the certificate specified in paragraph SUBMITTALS.

3.9 SYSTEM ACCEPTANCE

Following acceptance of the system, as-built drawings and O&M manuals must be delivered to the Contracting Officer for review and acceptance. Submit six sets of detailed as-built drawings. The drawings must show the system as installed, including deviations from both the project drawings and the approved shop drawings. These drawings must be submitted within two weeks after the final acceptance test of the system. At least one set of as-built (marked-up) drawings must be provided at the time of, or prior to the final acceptance test.

- a. Provide one set of full size paper as-built drawings and schematics. The drawings must be prepared electronically and sized no less than the contract drawings. Furnish one set of CDs or DVDs containing software back-up and CAD based drawings in latest version of AutoCAD, DXF and portable document formats of as-built drawings and schematics.
- b. Provide operating and maintenance (O&M) instructions and Posted Operating and Maintenance Instructions.

3.10 ONSITE TRAINING

Conduct a training course for the responding fire department and operating and maintenance personnel as designated by the Contracting Officer. Training must be performed on two separate days (to accommodate different shifts of Fire Department personnel) for a period of 4 hours of normal working time and must start after the system is functionally complete and after the final test report. The on-site training must cover all of the items contained in the approved Operating and Maintenance Instructions.

-- End of Section --

SECTION 21 30 00

FIRE PUMPS
04/08

PART 1 GENERAL

1.1 SUMMARY

Provide fire pumps in conformance with UFC 3-600-01, NFPA 20, NFPA 70, NFPA 24 and NFPA 72 and the Contract Documents. Devices and equipment for fire protection service must be UL Fire Prot Dir listed or FM APP GUIDE approved. Interpret all reference to the authority having jurisdiction to mean the Contracting Officer's Technical Representative.

1.2 SEQUENCING

1.2.1 Primary Fire Pump

Primary fire pump shall automatically operate when the pressure drops to its NFPA 20 setpoint or manually when the starter is operated. Pump shall continue to run until shut down manually.

1.2.2 Pressure Maintenance Pump

Pressure maintenance pump shall operate when the system pressure drops to its NFPA 20 setpoint. Pump shall automatically stop when the system pressure reaches its NFPA 20 stop setpoint and after the pump has operated for the minimum pump run time specified herein.

1.2.3 System Pressure Settings

It is the fire sprinkler contractor's responsibility to provide pressure set points to maintain the system in accordance with NFPA 20 requirements for a complete and code compliant operation.

1.3 FIRE PUMP INSTALLATION RELATED SUBMITTALS

The Qualified Fire Protection Engineer shall prepare a list of the submittals, from the Contract Submittal Register, that relate to the successful installation of the fire pump(s), no later than 7 days after the approval of the Qualified Fire Protection Engineer (QFPE) and the Manufacturer's Representative. The submittals identified on this list shall be accompanied by a letter of approval signed and dated by the QFPE when submitted to the Government.

1.4 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C111/A21.11

(2017) Rubber-Gasket Joints for
Ductile-Iron Pressure Pipe and Fittings

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B16.3	(2021) Malleable Iron Threaded Fittings, Classes 150 and 300
ASME B16.39	(2020) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300
ASME B16.5	(2020) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard

ASTM INTERNATIONAL (ASTM)

ASTM A183	(2014; R 2020) Standard Specification for Carbon Steel Track Bolts and Nuts
ASTM A193/A193M	(2023) Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service and Other Special Purpose Applications
ASTM A194/A194M	(2023) Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM A449	(2014; R 2020) Standard Specification for Hex Cap Screws, Bolts, and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use
ASTM A47/A47M	(1999; R 2022; E 2022) Standard Specification for Ferritic Malleable Iron Castings
ASTM A536	(1984; R 2019; E 2019) Standard Specification for Ductile Iron Castings
ASTM A563	(2021; E 2022a) Standard Specification for Carbon and Alloy Steel Nuts
ASTM B135	(2010) Standard Specification for Seamless Brass Tube
ASTM F436	(2011) Hardened Steel Washers

FM GLOBAL (FM)

FM APP GUIDE	(updated on-line) Approval Guide http://www.approvalguide.com/
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NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA MG 1	(2021) Motors and Generators
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NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 1963	(2019) Standard for Fire Hose Connections
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NFPA 20 (2022;TIA 21-1; TIA 21-2) Standard for the Installation of Stationary Pumps for Fire Protection

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code

NFPA 72 (2022; ERTA 22-1) National Fire Alarm and Signaling Code

UNDERWRITERS LABORATORIES (UL)

UL 448 (2020) Centrifugal Stationary Pumps for Fire-Protection Service

UL Fire Prot Dir (2012) Fire Protection Equipment Directory

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-101 (2014; Rev C) Color Code for Pipelines and for Compressed Gas Cylinders

UFC 3-600-01 (2016; with Change 6, 2021) Fire Protection Engineering for Facilities

1.5 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES.

Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Fire Pump Installation Related Submittals; G

Manufacturer's Representative; G

Qualifications of Welders; G

Qualifications of Installer; G

Qualified Fire Protection Engineer; G

No later than 14 days after the Notice to Proceed and prior to the submittal of the fire pump installation drawings

SD-02 Shop Drawings

Installation Drawings; G

3 copies

As-Built Drawings; G

Piping Layout; G

Pump Room; G

SD-03 Product Data

Catalog Data; G

Spare Parts

Preliminary Tests

Pump; G

Field Training; G

SD-06 Test Reports

Preliminary Test Procedures; G

At least 30 days prior to the proposed date and time to begin Preliminary Tests

Preliminary Test Report; G

3 copies of the completed Test Report, no later than 7 days after the completion of the Preliminary Tests.

Final Test Procedures; G

At least 21 days before starting final tests

Final Test Report; G

SD-07 Certificates

Preliminary Test Certification; G

Final Test Certification; G

SD-10 Operation and Maintenance Data

Operating and Maintenance Instructions; G

At least 14 days prior to conducting field training

Posted Operating and Maintenance Instructions; G

Flow Meter; G

Submit Data Package 2 for flow meter and controllers in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

1.6 EXTRA MATERIALS

Submit Spare Parts data for each different item of equipment and material specified. The data shall include a complete list of parts and supplies,

with current unit prices and source of supply, and a list of parts recommended by the manufacturer to be replaced after 1 year and 3 years of service. Include a list of special tools and test equipment required for maintenance and testing of the products supplied by the Contractor.

1.7 QUALITY ASSURANCE

1.7.1 Qualified Fire Protection Engineer

Work specified in this section shall be performed under the supervision of and certified by the Qualified Fire Protection Engineer (QFPE). The QFPE shall be regularly engaged in the design and installation of the type and complexity of system specified in the Contract documents, and shall have served in a similar capacity for at least three systems that have performed in the manner intended for a period of not less than 6 months. The Qualified Fire Protection Engineer shall be as approved in Section 21 13 13 WET PIPE SPRINKLER SYSTEM, FIRE PROTECTION paragraph 1.4.1, with the same duties noted in Division 21 specifications. The QFPE shall approve all submittals and certify the installation meets the requirements of the contract documents and referenced criteria.

1.7.2 Qualifications of Welders

Submit certificates of each welder's qualifications prior to site welding; certifications shall not be more than one year old.

1.7.3 Qualifications of Installer

Prior to installation, submit data for approval showing that the Contractor has successfully installed fire pumps and associated equipment of the same type and design as specified herein, or that he has a firm contractual agreement with a subcontractor having such required experience. The data shall include the names and locations of at least two installations where the Contractor, or the subcontractor referred to above, has installed such systems. Indicate the type and design of each system and certify that each system has performed satisfactorily in the manner intended for a period of not less than 18 months.

1.7.4 Preliminary Test Certification

When preliminary tests have been completed and corrections made, submit a signed and dated certificate with a request for a formal inspection and tests.

1.7.5 Final Test Certification

Concurrent with the Final Acceptance Test Report, submit certification by the QFPE that the fire pump installation is in accordance with the contract requirements, including signed approval of the Preliminary and Final Acceptance Test Reports. Submit data for approval showing the name and certification of all involved individuals with such qualifications at or prior to submittal of drawings.

1.7.6 Manufacturer's Representative

Work specified in this section shall be performed under the supervision of and certified by a representative of the fire pump manufacturer. Submit the name and documentation of certification of the proposed Manufacturer's Representative, concurrent with submittal of the Qualified Fire Protection

Engineer's Qualifications. The Manufacturer's Representative shall be regularly engaged in the installation of the type and complexity of fire pump(s) specified in the Contract documents, and shall have served in a similar capacity for at least three systems that have performed in the manner intended for a period of not less than 6 months.

1.8 DELIVERY, STORAGE, AND HANDLING

Protect all equipment delivered and placed in storage from the weather, excessive humidity and temperature variations, dirt and dust, or other contaminants. Additionally, all pipes shall be either capped or plugged until installed.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

- a. Materials and equipment shall be standard products of a manufacturer regularly engaged in the manufacture of such products and shall essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening.
- b. Submit manufacturer's catalog data included with the Fire Pump Installation Drawings for each separate piece of equipment proposed for use in the system. Catalog data shall indicate the name of the manufacturer of each item of equipment, with data annotated to indicate model to be provided. In addition, a complete equipment list that includes equipment description, model number and quantity shall be provided. Catalog data for material and equipment shall include, but not be limited to, the following:
 - (1) Fire pumps, drivers and controllers including manufacturer's certified shop test characteristic curve for each pump. Shop test curve may be submitted after approval of catalog data but shall be submitted prior to the final tests.
 - (2) Pressure maintenance pump and controller.
 - (3) Piping components.
 - (4) Valves, including gate, check, globe and relief valves.
 - (5) Gauges.
 - (6) Hose valve manifold test header and hose valves.
 - (7) Flow meter.
 - (8) Restrictive orifice union.
 - (9) Associated devices and equipment.
- c. All equipment shall have a nameplate that identifies the manufacturer's name, address, type or style, model or serial number, contract number and accepted date; capacity or size; system in which installed and system which it controls and catalog number. Pumps and motors shall have standard nameplates securely affixed in a conspicuous place and easy to read. Fire pump shall have nameplates and markings in accordance with UL 448. Electric motor nameplates

shall provide the minimum information required by NFPA 70, Section 430-7.

2.2 FIRE PUMP

Fire pumps shall be electric motor driven. Fire pump capacity shall be rated at minimum 1,250 gpm with a rated net pressure as required to satisfy the fire protection demand without exceeding 50 motor HP. Fire pump shall furnish not less than 150 percent of rated flow capacity at not less than 65 percent of rated net pressure. Pump shall be centrifugal horizontal split case fire pump. Pump shall be equipped with automatic air release devices. Pump shall be automatic start and stop. Pump shall conform to the requirements of UL 448. Fire pump discharge and suction gauges shall be oil-filled type.

2.2.1 Fire Pump

The fire pump shall be provided complete with fire pump electric motor driven, fire pump controller, jockey pump, jockey pump controller, double check valve backflow preventer, flow meter, pump test header, fire department connection, and all required accessories and appurtenances as required for a complete fire pump installation.

2.3 REQUIREMENTS FOR FIRE PROTECTION SERVICE

2.3.1 General Requirements

Materials and Equipment shall have been tested by Underwriters Laboratories, Inc. and/or listed in UL Fire Prot Dir or approved by Factory Mutual and listed in FM APP GUIDE. Where the terms "listed" or "approved" appear in this specification, such shall mean listed in UL Fire Prot Dir or FM APP GUIDE.

2.3.2 Alarms

Provide audible and visual alarms as required by NFPA 20 on the controller. Provide remote supervision by building fire alarm control unit as required by NFPA 20, in accordance with NFPA 72 under Section 23.8.5.9. Alarm signal shall be activated upon the following conditions: electric motor controller has operated into a pump running condition, loss of electrical power to electric motor starter, and phase reversal on line side of motor starter. Exterior alarm devices shall be weatherproof type. Provide alarm silencing switch and red signal lamp, with signal lamp arranged to come on when switch is placed in OFF position.

2.4 UNDERGROUND PIPING COMPONENTS

2.4.1 Refer Section 21 13 13, Wet Pipe Sprinkler Systems.

2.5 ABOVEGROUND PIPING COMPONENTS

2.5.1 Pipe Sizes 2 inches and Larger

2.5.1.1 Pipe

Piping shall be ASTM A53/A53M or ASTM A795/A795M, Weight Class STD (Standard), Schedule 40, Type E or Type S, Grade A; black steel pipe. Steel pipe shall be joined by means of flanges welded to the pipe or mechanical grooved joints only. Piping shall not be jointed by welding or

weld fittings. Suction piping shall be galvanized on the inside in accordance with NFPA 20.

2.5.1.2 Grooved Mechanical Joints and Fittings

Joints and fittings shall be designed for not less than 175 psi service and shall be the product of the same manufacturer. Fitting and coupling houses shall be malleable iron conforming to ASTM A47/A47M, Grade 32510; ductile iron conforming to ASTM A536, Grade 65-45-12. Gasket shall be the flush type that fills the entire cavity between the fitting and the pipe. Nuts and bolts shall be heat-treated steel conforming to ASTM A183 and shall be cadmium plated or zinc electroplated.

2.5.1.3 Flanges

Flanges shall be ASME B16.5, Class 150 flanges. Flanges shall be provided at valves, connections to equipment, and where indicated.

2.5.1.4 Gaskets

Gaskets shall be AWWA C111/A21.11, cloth inserted red rubber gaskets.

2.5.1.5 Bolts

Bolts shall be ASTM A449, Type 1, or 2, or ASTM A193/A193M, Grade B7. Bolts shall extend no less than three full threads beyond the nut with bolts tightened to the required torque.

2.5.1.6 Nuts

Nuts shall be ASTM A194/A194M, Grade 7, ASTM A193/A193M, Grade 5 ASTM A563, Grade C3, or DH3.

2.5.1.7 Washers

Washers shall meet the requirements of ASTM F436. Flat circular washers shall be provided under all bolt heads and nuts.

2.5.2 Piping Sizes 2 inches and Smaller

2.5.2.1 Steel Pipe

Steel piping shall be ASTM A795/A795M, Weight Class STD (Standard), Schedule 40, Type E or Type S, Grade A or ASTM A53/A53M, Weight Class XS (Extra Strong), zinc-coated steel pipe with threaded end connections. Fittings shall be ASME B16.3, Class 150, zinc-coated threaded fittings. Unions shall be ASME B16.39, Class 150, zinc-coated unions.

2.5.3 Pipe Hangers and Supports

Pipe hangers and support shall be MSS SP-58 or UL listed UL Fire Prot Dir or FM approved FM APP GUIDE and shall be the adjustable type. Finish of rods, nuts, washers, hangers, and supports shall be zinc-plated after fabrication.

2.5.4 Valves

Valves shall be UL listed UL Fire Prot Dir or FM approved FM APP GUIDE for fire protection service. Valves shall have flange or threaded end

connections.

2.5.4.1 Gate Valves and Control Valves

Gate valves and control valves shall be outside screw and yoke (O.S.&Y.) type which open by counterclockwise rotation. Butterfly-type control valves are not permitted.

2.5.4.2 Tamper Switch

The suction control valves, the discharge control valves, valves to test header and flow meter, and the by-pass control valves shall be equipped with valve tamper switches for monitoring by the fire alarm system.

2.5.4.3 Check Valve

Check valve shall be clear open, swing type check valve with flange or threaded inspection plate.

2.5.4.4 Circulating Relief Valve

An adjustable circulating relief valve shall be provided for each fire pump in accordance with NFPA 20.

2.5.5 Pipe Sleeves

A pipe sleeve shall be provided at each location where piping passes entirely through walls, ceilings, roofs, and floors, including pipe entering buildings from the exterior. Secure sleeves in position and location during construction. Provide sleeves of sufficient length to pass through entire thickness of walls, ceilings, and floors. Provide one inch minimum clearance between exterior of piping or pipe insulation, and interior of sleeve or core-drilled hole. Firmly pack space with mineral wool insulation. Seal space at both ends of the sleeve or core-drilled hole with plastic waterproof cement which will dry to a firm but pliable mass, or provide a mechanically adjustable segmented elastomeric seal. In fire walls and fire floors, a fire seal shall be provided between the pipe and the sleeve in accordance with Section 07 84 00 FIRESTOPPING. Firestopping materials must be furnished and installed by the Firestopping installer and shall conform to the requirements in Section 07 84 00 FIRESTOPPING.

- a. Sleeves in Masonry and Concrete Walls, Ceilings, Roofs, and Floors: Provide hot-dip galvanized steel, ductile-iron, or cast-iron pipe sleeves. Core drilling of masonry and concrete may be provided in lieu of pipe sleeves provided that cavities in the core-drilled hole be completely grouted smooth.
- b. Sleeves in Other Than Masonry and Concrete Walls, Ceilings, Roofs, and Floors: Provide galvanized steel sheet pipe not less than 0.90 psf.

2.5.6 Escutcheon Plates

Provide one-piece or split-hinge metal plates for piping entering floors, walls, and ceilings in exposed areas. Provide polished stainless steel or chromium-plated finish on copper alloy plates in finished spaces. Provide paint finish on plates in unfinished spaces. Plates shall be secured in place.

2.6 ELECTRIC MOTOR DRIVER

Motors, controllers, contactors, and disconnects shall be provided with their respective pieces of equipment, as specified herein and shall have electrical connections provided under Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Controllers and contactors shall have a maximum of 120-volt control circuits, and auxiliary contacts for use with the controls furnished. When motors and equipment furnished are larger than sizes indicated, the cost of providing additional electrical service and related work shall be included under this section. Motor shall conform to NEMA MG 1 Design B type. Integral size motors shall be the premium efficiency type in accordance with NEMA MG 1. Motor horsepower shall be of sufficient size so that the nameplate horsepower rating will not be exceeded throughout the entire published pump characteristic curve. The motor and fire pump controller shall be fully compatible. All controllers shall be solid state, soft start drive.

2.7 FIRE PUMP CONTROLLERS

Controllers shall be across the line or wye-delta type and UL listed UL Fire Prot Dir or FM approved FM APP GUIDE for fire pump service. Pump shall be arranged for automatic start, and manual push-button stop. Controllers shall be completely terminally wired, ready for field connections, and mounted in a NEMA Type 4 watertight and dust tight enclosure arranged so that controller current carrying parts will not be less than 12 inches above the floor. Controller shall be provided with voltage surge arresters installed in accordance with NFPA 20. Controllers shall be equipped with a bourdon tube pressure switch or a solid state pressure switch with independent high and low adjustments, automatic starting relay actuated from normally closed contacts, visual alarm lamps and supervisory power light. Controller shall be equipped with a thermostat switch with adjustable setting to monitor the pump room temperature and to provide an alarm when temperatures falls below 40 degrees F. Controller shall be equipped with a sequential start timer/relay feature to start multiple fire pumps in sequence.

2.7.1 Controllers for Electric Motor Driven Fire Pump

Controllers shall be electronic starting type. Controllers shall be designed for minimum 50 HP at 480 volts. Controllers shall have a short circuit rating of 100,000 amps r.m.s. symmetrical at 480 volts a.c. as indicated. Controller shall monitor pump running, loss of a phase or line power, phase reversal, and pump room temperature. Alarms shall be individually displayed in front of panel by lighting of visual lamps. Each lamp shall be labeled with rigid etched plastic labels. Controller shall be equipped with terminals for remote monitoring of pump running, pump power supply trouble (loss of power or phase and phase reversal), and pump room trouble (pump room temperature). Controller shall be equipped with a 7-day electric pressure recorder with 24-hour spring wound back-up. The pressure recorder shall provide a readout of the system pressure, time, and date. The controller shall be equipped with an externally operable isolating switch which manually operates the motor circuit. Means shall be provided in the controller for measuring current for all motor circuit conductors.

2.8 PRESSURE SENSING LINE

A completely separate pressure sensing line shall be provided for each fire pump and for the jockey pump. The sensing line shall be arranged in

accordance with Figure A-7-5.2.1. of NFPA 20. The sensing line shall be 1/2 inch H58 brass tubing complying with ASTM B135. The sensing line shall be equipped with two restrictive orifice unions each. Restricted orifice unions shall be ground-face unions with brass restricted diaphragms drilled for a 3/32 inch. Restricted orifice unions shall be mounted in the horizontal position, not less than 5 feet apart on the sensing line. Two test connections shall be provided for each sensing line. Test connections shall consist of two brass 1/2 inch globe valves and 1/4 inch gauge connection tee arranged in accordance with NFPA 20. One of the test connections shall be equipped with a 0 to 300 psi water oil-filled gauge. Sensing line shall be connected to the pump discharge piping between the discharge piping control valve and the check valve.

2.9 PRESSURE MAINTENANCE PUMP

2.9.1 General

Pressure maintenance pump shall be electric motor driven, horizontal shaft or in-line vertical shaft, centrifugal type. Pump shall draft from the suction supply side of the suction pipe gate valve of the fire pump and shall discharge into the system at the downstream side of the pump discharge gate valve. An approved indicating gate valve of the outside screw and yoke (O.S.&Y.) type shall be provided in the maintenance pump discharge and suction piping. Oil-filled water pressure gauge and approved check valve in the maintenance pump discharge piping shall be provided. Check valve shall be swing type with removable inspection plate.

2.9.2 Pressure Maintenance Pump Controller

Pressure maintenance pump controller shall be arranged for automatic and manual starting and stopping and equipped with a "manual-off-automatic" switch. The controller shall be completely prewired, ready for field connections, and wall-mounted in a NEMA Type 2 drip-proof enclosure. The controller shall be equipped with a bourdon tube pressure switch or a solid state pressure switch with independent high and low adjustments for automatic starting and stopping. A sensing line shall be provided connected to the pressure maintenance pump discharge piping between the control valve and the check valve. The sensing line shall conform to paragraph, PRESSURE SENSING LINE. The sensing line shall be completely separate from the fire pump sensing lines. An adjustable run timer shall be provided to prevent frequent starting and stopping of the pump motor. The run timer shall be set for 2 minutes.

2.10 PUMP BASE PLATE AND PAD

Provide a common base plate for each horizontal-shaft fire pump for mounting pump and driver unit. Construct the base plate of cast iron with raised lip tapped for drainage or welded steel shapes with suitable drainage. Provide each base plate for the horizontal fire pumps with a 1 inch galvanized steel drain line piped to the nearest floor drain. For vertical shaft pumps, pump head shall be provided with a cast-iron base plate and shall serve as the sole plate for mounting the discharge head assembly. Mount pump units and bases on a raised 4 or 6 inches reinforced concrete pad that is an integral part of the reinforced concrete floor.

2.11 HOSE VALVE MANIFOLD TEST HEADER

Hose valve test header shall be connected by ASME B16.5, Class 150 flange inlet connection. Hose valves shall be UL listed UL Fire Prot Dir or FM

approved FM APP GUIDE bronze hose gate valves with 2.5 inches American National Fire Hose Connection Screw Standard Threads (NH) in accordance with NFPA 1963. Each shall be equipped with a cap and chain, and located no more than 3 feet and no less than 2 feet above grade. Provide drain valve for any trapped piping.

2.12 FLOW METER

Meter shall be UL listed UL Fire Prot Dir or FM approved FM APP GUIDE as flow meters for fire pump installation with direct flow readout device. Flow meter shall be capable of metering any waterflow quantities between 50 percent and 150 percent of the rated flow of one pump. Arrange piping to permit flow meter to discharge to pump suction and to discharge through test header. The meter throttle valve and the meter control valves shall be O.S.&Y. valves. Provide automatic air release if flow meter piping between pump discharge and pump suction forms an inverted "U". Meter shall be of the venturi type.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before performing the work.

3.2 INSPECTION BY QUALIFIED FIRE PROTECTION ENGINEER

The Qualified Fire Protection Engineer shall periodically perform a thorough inspection of the fire pump installation, including visual observation of the pump while running, to assure that the installation conforms to the contract requirements. There shall be no excessive vibration, leaks, unusual noises, overheating, or other potential problems. Inspection shall include piping and equipment clearance, access, supports, and guards. Any discrepancy shall be brought to the attention of the Contracting Officer in writing, no later than three working days after the discrepancy is discovered. The QFPE shall witness the preliminary and final acceptance tests and, after completion of the inspections and a successful final acceptance test, shall sign test results and certify in writing that the installation the fire pump installation is in accordance with the contract requirements.

3.3 INSTALLATION

Equipment, materials, workmanship, fabrication, assembly, erection, installation, examination, inspection and testing shall be in accordance NFPA 20, except as modified herein. In addition, the fire pump shall be installed in accordance with the written instructions of the manufacturer.

3.3.1 Installation Drawings

Submit Fire Pump Installation Drawings consisting of a detailed plan view, detailed elevations and sections of the pump room, equipment and piping, drawn to a scale of not less than 1/2 inch = 1 foot. Drawings shall indicate equipment, piping, and associated pump equipment to scale. Indicate all clearance, such as those between piping and equipment; between equipment and walls, ceiling and floors; and for electrical working distance clearance around all electrical equipment. Include a legend identifying all symbols, nomenclatures, and abbreviations.

Indicate a complete piping and equipment layout including elevations and/or section views of the following:

- a. Fire pumps, controllers, piping, valves, and associated equipment.
- b. Sensing line for each pump including the pressure maintenance pump.
- c. Pipe hangers and supports.
- d. A one-line schematic diagram indicating layout and sizes of all piping, devices, valves and fittings.
- e. A complete point-to-point connection drawing of the pump power, control and alarm systems, as well as interior wiring schematics of each controller.

3.3.2 Pump Room Configuration

Provide detail plan view of the pump room including elevations and sections showing the fire pumps, associated equipment, and piping. Submit working drawings on sheets not smaller than 24 by 36 inches; include data for the proper installation of each system. Show piping schematic of pumps, devices, valves, pipe, and fittings. Provide an isometric drawing of the fire pump and all associated piping. Show point to point electrical wiring diagrams. Show piping layout and sensing piping arrangement. Include:

- a. Pumps, drivers, and controllers
- b. Hose valve manifold test header
- c. Circuit diagrams for pumps
- d. Wiring diagrams of each controller

3.3.3 Accessories

Tank supports, piping offsets, fittings, and any other accessories required shall be furnished as specified to provide a complete installation and to eliminate interference with other construction.

3.4 PIPE AND FITTINGS

Piping shall be inspected, tested and approved before burying, covering, or concealing. Fittings shall be provided for changes in direction of piping and for all connections. Changes in piping sizes shall be made using tapered reducing pipe fittings. Bushings shall not be used. Photograph all piping prior to burying, covering, or concealing.

3.4.1 Cleaning of Piping

Interior and ends of piping shall be clean and free of any water or foreign material. Piping shall be kept clean during installation by means of plugs or other approved methods. When work is not in progress, open ends of the piping shall be securely closed so that no water or foreign matter will enter the pipes or fittings. Piping shall be inspected before placing in position.

3.4.2 Threaded Connections

Jointing compound for pipe threads shall be polytetrafluoroethylene (PTFE) pipe thread tape conforming to ASTM D3308 or Teflon pipe thread paste and shall be applied to male threads only. Exposed ferrous pipe threads shall be provided with one coat of zinc molybdate primer applied to a minimum of dry film thickness of 1 mil.

3.4.3 Pipe Hangers and Supports

Additional hangers and supports shall be provided for concentrated loads in aboveground piping, such as for valves and risers.

3.4.3.1 Vertical Piping

Piping shall be supported at each floor, at not more than 10 foot intervals.

3.4.4 Underground Piping

See Section 21 13 13, Wet Pipe Sprinkler Systems. Flush lead-in per NFPA 20 without the use of the fire pump.

3.4.5 Grooved Mechanical Joint

Grooves shall be prepared according to the coupling manufacturer's instructions. Grooved fittings, couplings, and grooving tools shall be products of the same manufacturer. Pipe and groove dimensions shall comply with the tolerances specified by the coupling manufacturer. The diameter of grooves made in the field shall be measured using a "go/no-go" gauge, vernier or dial caliper, narrow-land micrometer, or other method specifically approved by the coupling manufacturer for the intended application. Groove width and dimension of groove from end of pipe shall be measured for each change in grooving tool setup to verify compliance with coupling manufacturer's tolerances. Grooved joints shall not be used in concealed locations, such as behind solid walls or ceilings, unless an access panel is shown on the drawings for servicing or adjusting the joint.

3.5 ELECTRICAL WORK

Electric motor and controls shall be in accordance with NFPA 20, NFPA 72 and NFPA 70, unless more stringent requirements are specified herein or are indicated on the drawings. Electrical wiring and associated equipment shall be provided in accordance with NFPA 20 and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide wiring in rigid metal conduit or intermediate metal conduit, except electrical metallic tubing conduit may be provided in dry locations not enclosed in concrete or where not subject to mechanical damage.

3.6 PIPE COLOR CODE MARKING

Color code marking of piping red as specified in Section 09 90 00 PAINTS AND COATINGS. Provide wrap around labels per MIL-STD-101 indicating direction of flow and type of fluid.

3.7 FLUSHING

The fire pump suction and discharge piping shall be flushed at 150 percent of rated capacity of each pump. The underground piping upstream of the

pump shall not be flushed by using the fire pumps. Flushing operations shall continue until water is clear, but not less than 10 minutes. Submit a signed and dated flushing certificate before requesting field testing.

3.8 Preliminary Test Procedures

Submit proposed procedures for Preliminary Tests at least 30 days prior to the proposed date and time to begin Preliminary Tests. Include test agenda indicating tests to be performed, duration of tests, test personnel and witnesses, flushing procedures, flow rates, method of measurement, flushing layout and apparatus, pump test apparatus and blank test forms.

3.9 Preliminary Tests

The Qualified Fire Protection Engineer shall take all readings and measurements. The Manufacturer's Representative and a representative of the fire pump controller manufacturer shall witness the complete operational testing of the fire pump and drivers. The fire pump controller manufacturer's representative shall be an experienced technician employed by the respective manufacturers and capable of demonstrating operation of all features of respective components including trouble alarms and operating features. Fire pumps, drivers and equipment shall be thoroughly inspected and tested to insure that the system is correct, complete, and ready for operation.

Tests shall ensure that pumps are operating at rated capacity, pressure and speed. Tests shall include manual starting and running to ensure proper operation and to detect leakage or other abnormal conditions, flow testing, automatic start testing, testing of automatic settings, sequence of operation check, test of required accessories; test of pump alarms devices and supervisory signals, test of pump cooling, operational test of relief valves, and test of automatic power transfer, if provided. Pumps shall run without abnormal noise, vibration or heating. If any component or system was found to be defective, inoperative, or not in compliance with the contract requirements during the tests and inspection, the corrections shall be made and the entire preliminary test shall be repeated.

Piping shall be hydrostatically tested at 200 psig for a period of 2-hours, or at least 50 psi in excess of the maximum pressure, when the maximum pressure in the system is in excess of 150 psi in accordance with NFPA 20.

Test Equipment: Provide all equipment and instruments necessary to conduct a complete final test, including 2.5 inch diameter hoses, playpipe nozzles, pitot tube gauges, portable digital tachometer, voltage and ampere meters, and calibrated oil-filled water pressure gauges. Provide all necessary supports to safely secure hoses and nozzles during the test. The Government will furnish water for the tests.

Fully enclose or properly guard coupling, rotating parts, gears, projecting equipment, etc. so as to prevent possible injury to persons that come in close proximity of the equipment. Conduct testing of the fire pumps in a safe manner and ensure that all equipment is safely secured. Hoses and nozzles used to conduct flow tests shall be in excellent condition and shall be safely anchored and secured to prevent any misdirection of the hose streams.

3.10 Preliminary Tests

Submit Preliminary Test Report, to include the Contractor's Material and Test Certificate for Underground Piping and the Contractor's Material and Test Certificate for Aboveground Piping, as well as the NFPA 20 Contractor's Material and Test Certificate for Fire Pump Systems, fire pump test data, gauge calibration certificates, sign-in sheet and Certified Curve. Include flushing test results. All items in the Report shall be signed by the QFPE and the Manufacturer's Representative.

3.11 Final Test Procedures

Submit proposed procedures for Final Tests at least 21 days prior to the proposed date and time to begin Final Tests. Include test agenda indicating tests to be performed, duration of tests, test personnel and witnesses, pump test apparatus and pump test forms from preliminary testing. Final Tests shall be witnessed by the QFPE and the Contracting Officer's Representative.

3.12 Final Tests

Tests shall ensure that pumps are operating at rated capacity, pressure and speed. Tests shall include manual starting and running to ensure proper operation and to detect leakage or other abnormal conditions, flow testing, automatic start testing, testing of automatic settings, sequence of operation check, test of required accessories; test of pump alarms, devices and supervisory signals, test of pump cooling, operational test of relief valves, and test of automatic power transfer, if provided. Pumps shall run without abnormal noise, vibration or heating. If any component or system was found to be defective, inoperative, or not in compliance with the contract requirements during the tests and inspection, the corrections shall be made and the entire final test shall be repeated.

Test Equipment: Provide all equipment and instruments necessary to conduct a complete final test, including 2.5 inch diameter hoses, playpipe nozzles, pitot tube gauges, portable digital tachometer, voltage and ampere meters, and calibrated oil-filled water pressure gauges. Provide all necessary supports to safely secure hoses and nozzles during the test. The Government will furnish water for the tests.

Flushing of the underground and hydrostatic testing are not required to be repeated during final testing. If the quantity of NFPA 20 required starts and stops were accomplished in Preliminary Testing, they are not required to be repeated in Final Testing, otherwise, complete the series.

3.13 Final Test Report

Submit Final Test Report, to include the Contractor's Material and Test Certificate for Underground Piping and the Contractor's Material and Test Certificate for Aboveground Piping, as well as the NFPA 20 Contractor's Material and Test Certificate for Fire Pump Systems, fire pump test data, gauge calibration certificates, sign-in sheet and Certified Curve. Include flushing test results. All items in the Report shall be signed by the QFPE. Include a copy of the Test Report in the Operation and Maintenance Manual.

3.14 Posted Operating and Maintenance Instructions

Submit system diagrams that show the layout of equipment, piping, and

typed condensed sequence of operation, wiring and control diagrams, and operation manuals explaining preventative maintenance procedures, methods of checking the system for normal, safe operation, and procedures for safely starting and stopping the system shall be framed under glass or laminated plastic. After approval, these Posted Operating and Maintenance Instructions shall be posted where directed. Posted O&M Instructions shall be framed, under glass, for pumps, drivers, controllers, and flow meters. Include system schematic, plans and sections, HVAC and their controls.

3.15 CLOSEOUT ACTIVITIES

3.15.1 Field Training

The QFPE and the Manufacturer's Representative shall conduct a training course for operating and maintenance personnel as designated by the Contracting Officer. Submit the proposed schedule for field training at least 14 days prior to the start of related training. Training shall be provided for a period of 8 hours of normal working time and shall start after the fire pump installation is functionally complete and after the Final Acceptance Test. The field instruction shall cover all of the items contained in the approved Operating and Maintenance Instructions. Submit manuals listing step-by-step procedures required for system startup, operation, shutdown, and routine maintenance. The manuals shall include the manufacturer's name, model number, parts list, list of parts and tools that should be kept in stock by the owner for routine maintenance including the name of a local supplier, simplified wiring and controls diagrams, troubleshooting guide, and recommended service organization (including address and telephone number) for each item of equipment. Data Package 3 shall be submitted for fire pumps and drivers in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. Each service organization submitted shall be capable of providing 4 hour onsite response to a service call on an emergency basis.

3.15.2 As-Built Drawings

Submit As-Built Drawings, no later than 14 days after completion of the Final Tests. Update the Fire Pump Installation Drawings to reflect as-built conditions after all related work is completed and shall be electronic on CDs.

3.16 PROTECTION

Carefully remove materials so as not to damage material which is to remain. Replace existing work damaged by the Contractor's operations with new work of the same construction.

-- End of Section --

SECTION 22 00 00

PLUMBING, GENERAL PURPOSE
05/24

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR-CONDITIONING, HEATING AND REFRIGERATION INSTITUTE (AHRI)

ANSI/AHRI 1160 I-P (2022) Performance Rating of Heat Pump Pool Heaters

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI Z21.10.1/CSA 4.1 (2019) Gas Water Heaters Vol. I, Storage Water Heaters with Input Ratings of 75,000 Btu Per Hour or Less

ANSI Z21.10.3/CSA 4.3 (2019) Gas-Fired Water Heaters Vol.III, Storage Water Heaters With Input Ratings Above 75,000 Btu Per Hour, Circulating and Instantaneous

ANSI Z21.22/CSA 4.4 (2015; R 2020) Relief Valves for Hot Water Supply Systems

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ANSI/ASHRAE 18 (2008; R 2013) Methods Of Testing For Rating Drinking Water Coolers With Self-Contained Mechanical Refrigeration

ASHRAE 90.1 - IP (2019) Energy Standard for Buildings Except Low-Rise Residential Buildings

ASHRAE 146 (2020) Method of Testing and Rating Pool Heaters (ANSI Approved)

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME A112.1.2 (2012; R 2017; R 2022) Air Gaps in Plumbing Systems (For Plumbing Fixtures and Water-Connected Receptors)

ASME A112.6.1M (1997; R 2017) Floor Affixed Supports for Off-the-Floor Plumbing Fixtures for Public Use

ASME A112.6.3 (2022) Floor Drains

ASME A112.6.4 (2022) Roof, Deck and Balcony Drains

ASME A112.14.1	(2003; R 2017; R 2022) Backwater Valves
ASME A112.18.1/CSA B125.1	(2018) Plumbing Supply Fittings
ASME A112.19.2/CSA B45.1	(2018; ERTA 2018) Standard for Vitreous China Plumbing Fixtures and Hydraulic Requirements for Water Closets and Urinals
ASME A112.19.3/CSA B45.4	(2022) Stainless Steel Plumbing Fixtures
ASME A112.36.2M	(2022) Cleanouts
ASME B1.20.1	(2013; R 2018) Pipe Threads, General Purpose (Inch)
ASME B16.3	(2021) Malleable Iron Threaded Fittings, Classes 150 and 300
ASME B16.4	(2021) Gray Iron Threaded Fittings; Classes 125 and 250
ASME B16.5	(2020) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.12	(2019) Cast Iron Threaded Drainage Fittings
ASME B16.15	(2018) Cast Copper Alloy Threaded Fittings Classes 125 and 250
ASME B16.18	(2021) Cast Copper Alloy Solder Joint Pressure Fittings
ASME B16.21	(2021) Nonmetallic Flat Gaskets for Pipe Flanges
ASME B16.22	(2021) Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B16.23	(2021) Cast Copper Alloy Solder Joint Drainage Fittings - DWV
ASME B16.24	(2022) Cast Copper Alloy Pipe Flanges, Flanged Fittings, and Valves Classes 150, 300, 600, 900, 1500, and 2500
ASME B16.29	(2022) Wrought Copper and Wrought Copper Alloy Solder-Joint Drainage Fittings - DWV
ASME B16.34	(2021) Valves - Flanged, Threaded and Welding End
ASME B16.50	(2021) Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings
ASME B16.51	(2013) Copper and Copper Alloy Press-Connect Pressure Fittings
ASME B31.1	(2022) Power Piping

ASME B31.5	(2022) Refrigeration Piping and Heat Transfer Components
ASME B31.9	(2020) Building Services Piping
ASME B40.100	(2022) Pressure Gauges and Gauge Attachments
ASME BPVC SEC IV	(2017) BPVC Section IV-Rules for Construction of Heating Boilers
ASME BPVC SEC IX	(2017; Errata 2018) BPVC Section IX-Welding, Brazing and Fusing Qualifications
ASME BPVC SEC VIII D1	(2019) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1
ASME CSD-1	(2021) Control and Safety Devices for Automatically Fired Boilers

AMERICAN SOCIETY OF SANITARY ENGINEERING (ASSE)

ASSE 1001	(2021) Performance Requirements for Atmospheric Type Vacuum Breakers
ASSE 1010	(2021) Performance Requirements for Water Hammer Arresters
ASSE 1011	(2017) Performance Requirements for Hose Connection Vacuum Breakers
ASSE 1012	(2023) Performance Requirements for Backflow Preventer with an Intermediate Atmospheric Vent
ASSE 1013	(2021) Performance Requirements for Reduced Pressure Principle Backflow Prevention Assemblies
ASSE 1016	(2017) Performance Requirements for Automatic Compensating Valves for individual Showers and Tub/Shower Combinations
ASSE 1017	(2023) Performance Requirements for Temperature Actuated Mixing Valves for Hot Water Distribution Systems - (ANSI approved 2010)
ASSE 1018	(2023) Performance Requirements for Trap Seal Primer Valves - Potable Water Supplied (ANSI Approved 2002)
ASSE 1019	(2023) Performance Requirements for Wall Hydrant with Backflow Protection and Freeze Resistance

ASSE 1020	(2020) Performance Requirements for Pressure Vacuum Breaker Assemblies
ASSE 1044	(2023) Performance Requirements for Trap Seal Primer - Drainage Types and Electric Design Types
ASSE 1069	(2020) Performance Requirements for Automatic Temperature Control Mixing Valves
ASSE 1070	(2020) Performance Requirements for Water Temperature Limiting Devices
ASSE 1071	(2012) Performance Requirements for Temperature Actuated Mixing Valves for Plumbed Emergency Equipment
ASSE 1072	(2020) Performance Requirements for Barrier Type Trap Seal Protection for Floor Drains

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA B300	(2018) Hypochlorites
AWWA B301	(2018) Liquid Chlorine
AWWA C203	(2020) Coal-Tar Protective Coatings and Linings for Steel Water Pipelines - Enamel and Tape - Hot-Applied
AWWA C606	(2022) Grooved and Shouldered Joints
AWWA C651	(2014) Standard for Disinfecting Water Mains
AWWA C652	(2019) Disinfection of Water-Storage Facilities
AWWA C700	(2020) Cold-Water Meters - Displacement Type, Metal Alloy Main Case
AWWA C701	(2019) Cold-Water Meters - Turbine Type for Customer Service
AWWA D100	(2021) Welded Steel Tanks for Water Storage

AMERICAN WELDING SOCIETY (AWS)

AWS A5.8/A5.8M	(2019) Specification for Filler Metals for Brazing and Braze Welding
AWS B2.2/B2.2M	(2016) Specification for Brazing Procedure and Performance Qualification

ASTM INTERNATIONAL (ASTM)

ASTM A47/A47M	(1999; R 2022; E 2022) Standard Specification for Ferritic Malleable Iron
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Castings

ASTM A53/A53M	(2022) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A74	(2021) Standard Specification for Cast Iron Soil Pipe and Fittings
ASTM A105/A105M	(2021) Standard Specification for Carbon Steel Forgings for Piping Applications
ASTM A183	(2014; R 2020) Standard Specification for Carbon Steel Track Bolts and Nuts
ASTM A193/A193M	(2023) Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service and Other Special Purpose Applications
ASTM A515/A515M	(2017; R2022) Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
ASTM A516/A516M	(2017) Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
ASTM A518/A518M	(1999; R 2022) Standard Specification for Corrosion-Resistant High-Silicon Iron Castings
ASTM A536	(1984; R 2019; E 2019) Standard Specification for Ductile Iron Castings
ASTM A888	(2023) Standard Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications
ASTM B32	(2020) Standard Specification for Solder Metal
ASTM B42	(2020) Standard Specification for Seamless Copper Pipe, Standard Sizes
ASTM B43	(2020) Standard Specification for Seamless Red Brass Pipe, Standard Sizes
ASTM B75/B75M	(2020) Standard Specification for Seamless Copper Tube
ASTM B88	(2022) Standard Specification for Seamless Copper Water Tube
ASTM B111/B111M	(2018) Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock

ASTM B117	(2019) Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM B152/B152M	(2019) Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar
ASTM B306	(2020) Standard Specification for Copper Drainage Tube (DWV)
ASTM B370	(2022) Standard Specification for Copper Sheet and Strip for Building Construction
ASTM B584	(2022) Standard Specification for Copper Alloy Sand Castings for General Applications
ASTM B813	(2016) Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube
ASTM C564	(2020a) Standard Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings
ASTM C920	(2018) Standard Specification for Elastomeric Joint Sealants
ASTM C1053	(2000; R 2010) Standard Specification for Borosilicate Glass Pipe and Fittings for Drain, Waste, and Vent (DWV) Applications
ASTM D1248	(2016) Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
ASTM D2000	(2018) Standard Classification System for Rubber Products in Automotive Applications
ASTM D2235	(2004; R 2016) Standard Specification for Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings
ASTM D2564	(2020) Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems
ASTM D2657	(2007; R 2015) Heat Fusion Joining Polyolefin Pipe and Fittings
ASTM D2661	(2014; E 2018) Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40, Plastic Drain, Waste, and Vent Pipe and Fittings
ASTM D2665	(2014) Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings

ASTM D2855	(2015) Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings
ASTM D2996	(2017) Standard Specification for Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
ASTM D3122	(1995; R 2009) Solvent Cements for Styrene-Rubber (SR) Plastic Pipe and Fittings
ASTM D3138	(2004; R 2016) Standard Specification for Solvent Cements for Transition Joints Between Acrylonitrile-Butadiene-Styrene (ABS) and Poly(Vinyl Chloride) (PVC) Non-Pressure Piping Components
ASTM D3139	(2019) Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals
ASTM D3212	(2020) Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals
ASTM D3311	(2017) Standard Specification for Drain, Waste, and Vent (DWV) Plastic Fittings Patterns
ASTM D4101	(2017) Standard Classification System and Basis for Specification for Polypropylene Injection and Extrusion Materials
ASTM D4586/D4586M	(2007; R 2018) Asphalt Roof Cement, Asbestos-Free
ASTM E1	(2014) Standard Specification for ASTM Liquid-in-Glass Thermometers
ASTM F477	(2014; R 2021) Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
ASTM F493	(2022) Standard Specification for Solvent Cements for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe and Fittings
ASTM F628	(2023) Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe with a Cellular Core
ASTM F891	(2023) Standard Specification for Coextruded Poly (Vinyl Chloride) (PVC) Plastic Pipe with a Cellular Core
ASTM F1290	(2019) Standard Practice for Electrofusion

Joining Polyolefin Pipe and Fittings

ASTM F1760 (2016; R 2020) Standard Specification for Coextruded Poly(Vinyl Chloride) (PVC) Non-Pressure Plastic Pipe Having Reprocessed-Recycled Content

ASTM F2389 (2023) Standard Specification for Pressure-rated Polypropylene (PP) Piping Systems

CAST IRON SOIL PIPE INSTITUTE (CISPI)

CISPI 301 (2018) Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications

CISPI 310 (2012) Coupling for Use in Connection with Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications

COPPER DEVELOPMENT ASSOCIATION (CDA)

CDA A4015 (2016; 14/17) Copper Tube Handbook

INTERNATIONAL ASSOCIATION OF PLUMBING AND MECHANICAL OFFICIALS (IAPMO)

IAPMO PS 117 (2021) Press Connections

IAPMO UPC (2024) Uniform Plumbing Code

INTERNATIONAL CODE COUNCIL (ICC)

ICC A117.1 (2017) Standard And Commentary Accessible and Usable Buildings and Facilities

ICC IPC (2024) International Plumbing Code

INTERNATIONAL SAFETY EQUIPMENT ASSOCIATION (ISEA)

ANSI/ISEA Z358.1 (2014; R 2020) American National Standard for Emergency Eyewash and Shower Equipment

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-25 (2018) Standard Marking System for Valves, Fittings, Flanges and Unions

MSS SP-58 (2018) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation

MSS SP-67 (2022) Butterfly Valves

MSS SP-70 (2011) Gray Iron Gate Valves, Flanged and Threaded Ends

MSS SP-71	(2018) Gray Iron Swing Check Valves, Flanged and Threaded Ends
MSS SP-72	(2010a) Ball Valves with Flanged or Butt-Welding Ends for General Service
MSS SP-78	(2011) Cast Iron Plug Valves, Flanged and Threaded Ends
MSS SP-80	(2019) Bronze Gate, Globe, Angle and Check Valves
MSS SP-85	(2011) Gray Iron Globe & Angle Valves Flanged and Threaded Ends
MSS SP-110	(2010) Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends

NACE INTERNATIONAL (NACE)

NACE SP0169	(2013) Control of External Corrosion on Underground or Submerged Metallic Piping Systems
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NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA MG 1	(2021) Motors and Generators
NEMA MG 11	(1977; R 2012) Energy Management Guide for Selection and Use of Single Phase Motors

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 31	(2024; TIA 23-1) Standard for the Installation of Oil-Burning Equipment
NFPA 54	(2024) National Fuel Gas Code
NFPA 90A	(2024) Standard for the Installation of Air Conditioning and Ventilating Systems

NSF INTERNATIONAL (NSF)

NSF 372	(2022) Drinking Water System Components - Lead Content
NSF/ANSI 14	(2023) Plastics Piping System Components and Related Materials
NSF/ANSI 61	(2022) Drinking Water System Components - Health Effects

PLASTIC PIPE AND FITTINGS ASSOCIATION (PPFA)

PPFA Fire Man (2016) Firestopping: Plastic Pipe in Fire
Resistive Construction

PLUMBING AND DRAINAGE INSTITUTE (PDI)

PDI WH 201 (2010) Water Hammer Arresters Standard

POOL & HOT TUB ALLIANCE (PHTA)

ANSI/APSP-16 (2017) American National Standard for
Suction Outlet Fitting Assemblies (SOFA)
for Use in Pools, Spas and Hot Tubs

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE J1508 (2023) Hose Clamp Specifications

U.S. DEPARTMENT OF ENERGY (DOE)

Energy Star (1992; R 2006) Energy Star Energy
Efficiency Labeling System (FEMP)

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA SM 9223 (2004) Enzyme Substrate Coliform Test

PL 93-523 (1974; A 1999) Safe Drinking Water Act

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

10 CFR 430 Energy Conservation Program for Consumer
Products

21 CFR 175 Indirect Food Additives: Adhesives and
Components of Coatings

40 CFR 141.80 National Primary Drinking Water
Regulations; Control of Lead and Copper;
General Requirements

UNDERWRITERS LABORATORIES (UL)

UL 174 (2004; Reprint Oct 2023) UL Standard for
Safety Household Electric Storage Tank
Water Heaters

UL 399 (2017; Reprint May 2019) UL Standard for
Safety Drinking Water Coolers

UL 499 (2014; Reprint May 2023) UL Standard for
Safety Electric Heating Appliances

UL 732 (2023) UL Standard for Safety Oil-Fired
Storage Tank Water Heaters

UL 1951 (2011; Reprint Jun 2020) UL Standard for
Safety Electric Plumbing Accessories

1.2 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Plumbing System; G

SD-03 Product Data

Backflow Prevention Assemblies; G

Recycled Content for Steel Pipe; S

Recycled Content for Cast Iron Pipe; S

Swimming Pool Suction Fittings; G

Press Fittings; G

Fixtures

Shower Faucets; G

Flush Valve Water Closets

WaterSense Label for Flush Valve Water Closet; S

Flush Valve Urinals

WaterSense Label for Urinal; S

Wall Hung Lavatories

Countertop Lavatories

Kitchen Sinks

Service Sinks

Drinking-Water Coolers; G

Energy Star Label for Freestanding Bottled Water Coolers/Dispensers;
S

WaterSense Label for Showerhead; S

Water Heaters; G

Energy Star Label for Gas Storage Water Heater; S

Energy Star Label for Gas Instantaneous Water Heater; S

Pumps; G

Welding

Vibration-Absorbing Features; G

Plumbing System

Thermostatic Mixing Valves

Temperature Controlled Mixing Valve

Point-Of-Use Mixing Valve

Automatic Temperature And/Or Pressure Compensating Valve

Temperature Actuated Mixing Valve

Single Supply Line Automatic Temperature Control

SD-06 Test Reports

Tests, Flushing and Disinfection

Test of Backflow Prevention Assemblies; G.

SD-07 Certificates

Materials and Equipment

Bolts

SD-10 Operation and Maintenance Data

Plumbing System; G

1.3 SHOP DRAWINGS

Submit Plumbing System Detail drawings consisting of schedules, performance charts, instructions, diagrams, and other information to illustrate the requirements and operations of systems that are not covered by the Plumbing Code. Submit Plumbing System Detail drawings for the complete plumbing system including piping layouts and locations of connections; dimensions for roughing-in, foundation, and support points; schematic diagrams and wiring diagrams or connection and interconnection diagrams. Detail drawings must indicate clearances required for maintenance and operation. Where piping and equipment are to be supported other than as indicated, details must include loadings and proposed support methods. Mechanical drawing plans, elevations, views, and details, must be drawn to scale.

1.4 STANDARD PRODUCTS

Specified materials and equipment must be standard products of a manufacturer regularly engaged in the manufacture of such products. Specified equipment must essentially duplicate equipment that has performed satisfactorily at least 2 years prior to bid opening. Standard products must have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use must include applications of equipment and materials under similar circumstances and of similar size. The product must have been for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2 year period.

Where equipment is specified to conform to requirements of the ASME Boiler and Pressure Vessel Code, the design, fabrication, and installation must conform to the code and a certificate must be submitted for the equipment.

1.4.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturer's factory or laboratory tests, can be shown.

1.4.2 Service Support

The equipment items must be supported by service organizations. Submit a certified list of qualified permanent service organizations for support of the equipment which includes their addresses and qualifications. These service organizations must be reasonably convenient to the equipment installation and able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

1.4.3 Manufacturer's Nameplate

Each item of equipment must have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

1.4.4 Modification of References

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "must" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction", or words of similar meaning, to mean the Contracting Officer.

1.4.4.1 Definitions

For the International Code Council (ICC) Codes referenced in the contract documents, advisory provisions must be considered mandatory, the word "should" must be interpreted as "must." Reference to the "code official" must be interpreted to mean the "Contracting Officer." For Navy owned property, references to the "owner" must be interpreted to mean the "Contracting Officer." For leased facilities, references to the "owner" must be interpreted to mean the "lessor." References to the "permit holder" must be interpreted to mean the "Contractor."

1.4.4.2 Administrative Interpretations

For ICC Codes referenced in the contract documents, the provisions of Chapter 1, "Administrator," do not apply. These administrative requirements are covered by the applicable Federal Acquisition Regulations (FAR) included in this contract and by the authority granted to the Officer in Charge of Construction to administer the construction of this project. References in the ICC Codes to sections of Chapter 1, must be applied appropriately by the Contracting Officer as authorized by his administrative cognizance and the FAR.

1.5 DELIVERY, STORAGE, AND HANDLING

Handle, store, and protect equipment and materials to prevent damage before and during installation in accordance with the manufacturer's recommendations, and as approved by the Contracting Officer. Replace damaged or defective items.

1.6 PERFORMANCE REQUIREMENTS

1.6.1 Welding

Piping must be welded in accordance with qualified procedures using performance-qualified welders and welding operators. Submit a copy of qualified procedures and a list of names and identification symbols of qualified welders and welding operators. Procedures and welders must be qualified in accordance with ASME BPVC SEC IX. Welding procedures qualified by others, and welders and welding operators qualified by another employer, may be accepted as permitted by ASME B31.9, unless temperature and pressure limits specified then may be accepted as permitted by ASME B31.1. The Contracting Officer must be notified 24 hours in advance of tests, and the tests must be performed at the work site if practicable. Welders or welding operators must apply their assigned symbols near each weld they make as a permanent record.

1.6.2 Cathodic Protection and Pipe Joint Bonding

Cathodic protection and pipe joint bonding systems must be in accordance with

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1.7 REGULATORY REQUIREMENTS

Unless otherwise required herein, plumbing work must be in accordance with ICC IPC.

1.8 PROJECT/SITE CONDITIONS

The Contractor must become familiar with details of the work, verify dimensions in the field, and advise the Contracting Officer of any discrepancy before performing any work.

1.9 INSTRUCTION TO GOVERNMENT PERSONNEL

Furnish the services of competent instructors to give full instruction to the designated Government personnel in the adjustment, operation, and maintenance, including pertinent safety requirements, of the specified

equipment or system. Instructors must be thoroughly familiar with all parts of the installation and must be trained in operating theory as well as practical operation and maintenance work. Submit Plumbing System Operation and Maintenance Data in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

Instruction must be given during the first regular work week after the equipment or system has been accepted and turned over to the Government for regular operation. The number of man-days (8 hours per day) of instruction furnished must be as specified in the individual section. When more than 4 man-days of instruction are specified, use approximately half of the time for classroom instruction. Use other time for instruction with the equipment or system. When significant changes or modifications in the equipment or system are made under the terms of the contract, provide additional instruction to acquaint the operating personnel with the changes or modifications.

1.10 ACCESSIBILITY OF EQUIPMENT

Install all work so that parts requiring periodic inspection, operation, maintenance, and repair are readily accessible. Install concealed valves, expansion joints, controls, dampers, and equipment requiring access, in locations freely accessible through access doors.

PART 2 PRODUCTS

2.1 MATERIALS

Materials for various services must be in accordance with TABLES I and II.

Cement pipe must contain recycled content as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE. Pipe schedules must be selected based on service requirements. Pipe fittings must be compatible with the applicable pipe materials. Plastic pipe, fittings, and solvent cement must meet NSF/ANSI 14 and must be NSF listed for the service intended. Plastic pipe, fittings, and solvent cement used for potable hot and cold water service must bear the NSF seal "NSF-PW." Polypropylene pipe and fittings must conform to dimensional requirements of Schedule 40, Iron Pipe size and must comply with NSF/ANSI 14, NSF/ANSI 61 and ASTM F2389. Polypropylene piping that will be exposed to UV light must be provided with a Factory applied UV resistant coating. Pipe threads (except dry seal) must conform to ASME B1.20.1. Grooved pipe couplings and fittings must be from the same manufacturer. Material or used in any potable water system intended for human consumption be certified in accordance with NSF 372 with the exception of brazing materials. In line devices such as water meters, building valves, check valves, meter stops, valves, fittings and back flow preventers must comply with PL 93-523 and NSF/ANSI 61, Section 8. End point devices such as drinking water fountains, lavatory faucets, kitchen and bar faucets, residential ice makers, supply stops and end point control valves used to dispense water for drinking must meet the requirements of NSF/ANSI 61, Section 9. Hubless cast-iron soil pipe must not be installed underground, under concrete floor slabs, or in crawl spaces below kitchen floors (for Air Force/Army/Navy projects). Plastic pipe must not be installed in air plenums. Plastic pipe must not be installed in a pressure piping system in buildings greater than three stories including any basement levels.

2.1.1 Pipe Joint Materials

Grooved pipe and hubless cast-iron soil pipe must not be used

underground. Solder containing lead must not be used with copper pipe. Cast iron soil pipe and fittings must be marked with the collective trademark of the Cast Iron Soil Institute. Joints and gasket materials must conform to the following:

- a. Coupling for Cast-Iron Pipe: for hub and spigot type ASTM A74, AWWA C606. For hubless type: CISPI 310.
- b. Coupling for Steel Pipe: AWWA C606.
- c. Couplings for Grooved Pipe: Ductile Iron ASTM A536 (Grade 65-45-12). Copper ASTM B584.
- d. Flange Gaskets: Gaskets must be made of non-asbestos material in accordance with ASME B16.21. Gaskets must be flat, 1/16 inch thick, and contain Aramid fibers bonded with Styrene Butadiene Rubber (SBR) or Nitro Butadiene Rubber (NBR). Gaskets must be the full face or self centering flat ring type. Gaskets used for hydrocarbon service must be bonded with NBR.
- e. Brazing Material: Brazing material must conform to AWS A5.8/A5.8M, BCuP-5.
- f. Brazing Flux: Flux must be in paste or liquid form appropriate for use with brazing material. Flux must be as follows: lead-free; have a 100 percent flushable residue; contain slightly acidic reagents; contain potassium borides; and contain fluorides.
- g. Solder Material: Solder metal must conform to ASTM B32.
- h. Solder Flux: Flux must be liquid form, non-corrosive, and conform to ASTM B813, Standard Test 1.
- i. PTFE Tape: PTFE Tape, for use with Threaded Metal or Plastic Pipe.
- j. Rubber Gaskets for Cast-Iron Soil-Pipe and Fittings (hub and spigot type and hubless type): ASTM C564.
- k. Rubber Gaskets for Grooved Pipe: ASTM D2000, maximum temperature 230 degrees F.
- l. Flexible Elastomeric Seals: ASTM D3139, ASTM D3212 or ASTM F477.
- m. Bolts and Nuts for Grooved Pipe Couplings: Heat-treated carbon steel, ASTM A183.
- n. Solvent Cement for Transition Joints between ABS and PVC Nonpressure Piping Components: ASTM D3138.
- o. Plastic Solvent Cement for ABS Plastic Pipe: ASTM D2235.
- p. Plastic Solvent Cement for PVC Plastic Pipe: ASTM D2564 and ASTM D2855.
- q. Plastic Solvent Cement for CPVC Plastic Pipe: ASTM F493.
- r. Flanged fittings including, but not limited to, flanges, bolts, nuts and bolt patterns must be in accordance with ASME B16.5 class 150 and must have the manufacturer's trademark affixed in accordance with MSS SP-25. Flange material must conform to ASTM A105/A105M. Blind

flange material must conform to ASTM A516/A516M cold service and ASTM A515/A515M for hot service. Bolts must be high strength or intermediate strength with material conforming to ASTM A193/A193M. Submit written certification by the bolt manufacturer that the bolts furnished comply with the specified requirements.

- s. Plastic Solvent Cement for Styrene Rubber Plastic Pipe: ASTM D3122.
- t. Press fittings for Copper Pipe and Tube: Copper press fittings must conform to the material and sizing requirements of ASME B16.51 and performance criteria of IAPMO PS 117. Sealing elements for copper press fittings must be EPDM, FKM or HNBR. Sealing elements must be factory installed or an alternative supplied fitting manufacturer. Sealing element must be selected based on manufacturer's approved application guidelines. Provide manufacturer data to show product has been installed on multiple projects of similar type.
- u. Copper tubing must conform to ASTM B88, Type K, L or M.
- v. Heat-fusion joints for polypropylene piping: ASTM F2389.

2.1.2 Miscellaneous Materials

Miscellaneous materials must conform to the following:

- a. Water Hammer Arrester: PDI WH 201. Water hammer arrester must be diaphragm type.
- b. Copper, Sheet and Strip for Building Construction: ASTM B370.
- c. Asphalt Roof Cement: ASTM D4586/D4586M.
- d. Hose Clamps: SAE J1508.
- e. Supports for Off-The-Floor Plumbing Fixtures: ASME A112.6.1M.
- f. Metallic Cleanouts: ASME A112.36.2M.
- g. Plumbing Fixture Setting Compound: A preformed flexible ring seal molded from hydrocarbon wax material. The seal material must be nonvolatile nonasphaltic and contain germicide and provide watertight, gastight, odorproof and verminproof properties.
- h. Coal-Tar Protective Coatings and Linings for Steel Water Pipelines: AWWA C203.
- i. Hypochlorites: AWWA B300.
- j. Liquid Chlorine: AWWA B301.
- k. Gauges - Pressure and Vacuum Indicating Dial Type - Elastic Element: ASME B40.100.
- l. Thermometers: ASTM E1. Mercury must not be used in thermometers.

2.1.3 Pipe Insulation Material

Insulation must be as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.2 PIPE HANGERS, INSERTS, AND SUPPORTS

Pipe hangers, inserts, and supports must conform to MSS SP-58.

2.3 VALVES

Valves must be provided on supplies to equipment and fixtures. Valves 2-1/2 inches and smaller must be bronze with threaded bodies for pipe and solder-type connections for tubing. Valves 3 inches and larger must have flanged iron bodies and bronze trim. Pressure ratings must be based upon the application. Grooved end valves may be provided if the manufacturer certifies that the valves meet the performance requirements of applicable MSS standard. Valves must conform to the following standards:

Description	Standard
Butterfly Valves	MSS SP-67
Cast-Iron Gate Valves, Flanged and Threaded Ends	MSS SP-70
Cast-Iron Swing Check Valves, Flanged and Threaded Ends	MSS SP-71
Ball Valves with Flanged Butt-Welding Ends for General Service	MSS SP-72
Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends	MSS SP-110
Cast-Iron Plug Valves, Flanged and Threaded Ends	MSS SP-78
Bronze Gate, Globe, Angle, and Check Valves	MSS SP-80
Steel Valves, Socket Welding and Threaded Ends	ASME B16.34
Cast-Iron Globe and Angle Valves, Flanged and Threaded Ends	MSS SP-85
Backwater Valves	ASME A112.14.1
Vacuum Relief Valves	ANSI Z21.22/CSA 4.4

Water Heater Drain Valves	ASME BPVC SEC IV, Part HLW-810: Requirements for Potable-Water Heaters Bottom Drain Valve
Trap Seal Primer Valves	ASSE 1018
Temperature and Pressure Relief Valves for Hot Water Supply Systems	ANSI Z21.22/CSA 4.4
Temperature and Pressure Relief Valves for Automatically Fired Hot Water Boilers	ASME CSD-1 Safety Code No., Part CW, Article 5

2.3.1 Backwater Valves

Backwater valves must be either separate from the floor drain or a combination floor drain, P-trap, and backwater valve, as indicated on drawings. Valves must have cast-iron bodies with cleanouts large enough to permit removal of interior parts. Valves must be of the flap type, hinged or pivoted, with revolving disks. Hinge pivots, disks, and seats must be nonferrous metal. Disks must be slightly open in a no-flow no-backwater condition. Cleanouts must extend to finished floor and be fitted with threaded countersunk plugs.

2.3.2 Wall Faucets

Wall faucets with vacuum-breaker backflow preventer must be brass with 3/4 inch male inlet threads, hexagon shoulder, and 3/4 inch hose connection. Faucet handle must be securely attached to stem.

2.3.3 Wall Hydrants (Frostproof)

ASSE 1019 with vacuum-breaker backflow preventer must have a nickel-brass or nickel-bronze wall plate and flange with nozzle and detachable key handle. A brass or bronze operating rod must be provided within a galvanized iron casing of sufficient length to extend through the wall so that the valve is inside the building, and the portion of the hydrant between the outlet and valve is self-draining. A brass or bronze valve with coupling and union elbow having metal-to-metal seat must be provided. Valve rod and seat washer must be removable through the face of the hydrant. The hydrant must have 3/4 inch exposed hose thread on spout and 3/4 inch male pipe thread on inlet.

2.3.4 Lawn Faucets

Lawn faucets must be brass, with either straight or angle bodies, and must be of the compression type. Body flange must be provided with internal pipe thread to suit 3/4 inch pipe. Body must be suitable for wrench grip. Faucet spout must have 3/4 inch exposed hose threads. Faucet handle must be securely attached to stem.

2.3.5 Yard Hydrants

Yard box or post hydrants must have valve housings located below frost lines. Water from the casing must be drained after valve is shut off. Hydrant must be bronze with cast-iron box or casing guard. "T" handle key must be provided.

2.3.6 Outlet Boxes

2.3.6.1 Washer Box

One-piece, recessed, metal box with quarter turn shut-off valves, water hammer arresters 1/2 inch hot and cold supplies, 2 inch drain.

2.3.6.2 Ice Maker Box

One-piece, recessed, metal box with quarter turn shut-off valves, 1/2 inch supply.

2.3.7 Relief Valves

Water heaters and hot water storage tanks must have a combination pressure and temperature (P&T) relief valve. The pressure relief element of a P&T relief valve must have adequate capacity to prevent excessive pressure buildup in the system when the system is operating at the maximum rate of heat input. The temperature element of a P&T relief valve must have a relieving capacity which is at least equal to the total input of the heaters when operating at their maximum capacity. Relief valves must be rated according to ANSI Z21.22/CSA 4.4. Relief valves for systems where the maximum rate of heat input is less than 200,000 Btuh must have 3/4 inch minimum inlets, and 3/4 inch outlets. Relief valves for systems where the maximum rate of heat input is greater than 200,000 Btuh must have 1 inch minimum inlets, and 1 inch outlets. The discharge pipe from the relief valve must be the size of the valve outlet.

2.3.8 Thermostatic Mixing Valves

Each valve must be constructed to control the mixing of hot and cold water and to deliver water at a desired temperature regardless of pressure or input temperature changes. The control element must be of an approved type. The body must be of heavy cast bronze, and interior parts must be brass, bronze, corrosion-resisting steel or copper. The valve must be equipped with necessary stops, check valves, unions, and sediment strainers on the inlets.

2.3.9 Temperature Controlled Mixing Valve

Provide an ASSE 1017 temperature controlled (master mixing valve) to lower temperature per UFC 3-420-01 immediately downstream of the water heater or storage tank as close to the fixture(s) as possible in order to reduce the amount of stored tempered water in the pipes in accordance with ASSE 1017.

2.3.10 Point-of-Use Mixing Valve

Provide a point-of-use mixing valve in accordance with ASSE 1070 at lavatories, hand-wash sinks, and washfountain locations. Point-of-use mixing valve must limit the tempered water to not greater than 110 degrees F.

2.3.11 Automatic Temperature and/or Pressure Compensating Valve

Provide automatic temperature and/or pressure compensating valve installed at each individual shower or tub/shower combination in accordance with ASSE 1016. The compensating valve must be integrated with each individual shower or tub/shower combination valve and must be installed at point of use. The valve must be equipped with a device to limit the maximum temperature to 120 degrees F.

2.3.12 Temperature Actuated Mixing Valve

Provide ASSE 1071 temperature actuated mixing valve to provide tepid water for emergency eyewash, shower/eyewash, drench shower and combination units that comply with ANSI/ISEA Z358.1. Valves must have a means to limit the maximum outlet temperature and must include a means of preventing cross-flow. Valves can be located in a wall-mounted bracket.

2.3.13 Single Supply Line Automatic Temperature Control

Provide ASSE 1069 automatic temperature control valve on single supply line to gang showers or sitz baths to provide tempered water control to multiple fixtures. Valves must be installed where end user does not have means to adjust temperature setting. Temperature setting must be set as indicated with a maximum set point of 120 degrees F.

2.4 FIXTURES

Submit list of fixtures with manufacturer, model, and flow rate. Water closet replacements in major renovations may have a flush valve of up to 1.6 GPF to accommodate existing plumbing capacity. Fixtures for use by the physically handicapped must be in accordance with ICC A117.1. Vitreous China, nonabsorbent, hard-burned, and vitrified throughout the body must be provided. Porcelain enameled ware must have specially selected, clear white, acid-resisting enamel coating evenly applied on surfaces. No fixture will be accepted that shows cracks, crazes, blisters, thin spots, or other flaws. Fixtures must be equipped with appurtenances such as traps, faucets, stop valves, and drain fittings. Each fixture and piece of equipment requiring connections to the drainage system, except grease interceptors, must be equipped with a trap. Brass expansion or toggle bolts capped with acorn nuts must be provided for supports, and polished chromium-plated pipe, valves, and fittings must be provided where exposed to view. Fixtures with the supply discharge below the rim must be equipped with backflow preventers. Internal parts of flush valves and flushometer valves, shower mixing valves, shower head face plates, pop-up stoppers of lavatory waste drains, and pop-up stoppers and overflow tees and shoes of bathtub waste drains must be copper alloy with all visible surfaces chrome plated.

2.4.1 Flush Valve Water Closets

2.4.1.1 Flush Valve Water Closet Type and Mount

ASME A112.19.2/CSA B45.1, white vitreous china, siphon jet, elongated bowl, wall mounted, wall outlet, provide with carrier. Top of toilet seat height above floor must be 14 to 15 inches, except 17 to 19 inches for wheelchair water closets. Provide wax bowl ring including plastic sleeve. Provide white solid plastic elongated.

2.4.1.2 Flush Valve Water Closet Flush and Flow

Water flushing volume of the water closet and flush valve combination must

not exceed 1.28 gallons per flush. Water closets must meet the EPA WaterSense product definition and must be EPA WaterSense labeled products. Provide data identifying WaterSense label for flush valve water closet. Fixtures that require the WaterSense label but are located in countries where the label is unavailable, see table below or see <https://uwla.eu/> for WaterSense label substitutes.

WaterSense Equivalencies	
Australia	WELs
Canada	WaterSense

Non-Mandatory Labels*	
European Union	European Water Label
Taiwan	Water Saving Label
China, Hong Kong	WELS

*Water efficiency labels recognized as market transformational, and are recommended, but not required for LEED projects.

2.4.1.3 Flush Valve Water Closet Control Valve

Provide large diameter flush valve including angle control-stop valve, vacuum breaker, tail pieces, slip nuts, and wall plates; exposed to view components must be chromium-plated or polished stainless steel. Flush valves must be nonhold-open type. Mount flush valves not less than 11 inches above the fixture. Mounted height of flush valve must not interfere with the hand rail in ADA stalls.

2.4.2 Flush Valve Urinals

ASME A112.19.2/CSA B45.1, white vitreous china, wall-mounted, wall outlet, siphon jet, integral trap, and extended side shields. Provide urinal with the rim 24 inches above the floor. Water flushing volume of the urinal and flush valve combination must not exceed 0.5 gallons per flush. Urinals must be EPA WaterSense labeled products. Provide data identifying WaterSense label for urinal. Fixtures that require the WaterSense label but are located in countries where the label is unavailable, see table below or see <https://uwla.eu/> for WaterSense label substitutes.

WaterSense Equivalencies	
Australia	WELs
Canada	WaterSense

Non-Mandatory Labels*	
European Union	European Water Label
Taiwan	Water Saving Label
China, Hong Kong	WELS

*Water efficiency labels recognized as market transformational, and are recommended, but not required for LEED projects.

Provide ASME A112.6.1M concealed chair carriers with vertical steel pipe supports. Provide large diameter flush valve including angle control-stop valve, vacuum breaker, tail pieces, slip nuts, and wall plates; exposed to view components must be chromium-plated or polished stainless steel. Flush valves must be nonhold-open type. Mount flush valves not less than 11 inches above the fixture.

2.4.3 Wall Hung Lavatories

ASME A112.19.2/CSA B45.1, white vitreous china, type, minimum dimensions of 16 inches wide by 16 inches front to rear, with supply openings for use with top mounted centerset faucets, and openings for concealed arm carrier installation. Provide aerator with faucet. Provide lavatory faucets and accessories meeting the flow rate and product requirements of the paragraph LAVATORIES. Provide ASME A112.6.1M concealed chair carriers with vertical steel pipe supports and concealed arms for the lavatory. Mount lavatory with the front rim 34 inches above floor and with 29 inches minimum clearance from bottom of the front rim to floor. Provide top mounted washerless centerset lavatory faucets. Provide piping covers for P-traps, valves, and exposed drain piping per ADA requirement.

2.4.4 Countertop Lavatories

ASME A112.19.2/CSA B45.1, white vitreous china,, minimum dimensions of 19 inches wide by 17 inches front to rear, with supply openings for use with top mounted centerset faucets. Furnish template and mounting kit by lavatory manufacturer. Provide lavatory faucets and accessories meeting the flow rate and product requirements of the paragraph LAVATORIES. Mount counter with the top surface 34 inches above floor and with 29 inches minimum clearance from bottom of the counter face to floor. Provide top mounted washerless centerset lavatory faucets.

2.4.5 Lavatory Systems, Single or Multiple Stations

ASME A112.18.1/CSA B125.1, provide wall hung, solid surface counter with integral bowls and 16-1/8 inches access panel. Provide with one bowls. Height to rim dimensions 34 inches , provide manufacturer's standard, chrome plated solid brass faucet at each bowl with hard wired, sensor activated control. Provide ASSE 1070 point-of-use mixing valve with check stops per single user station, set to maximum 110 degrees F.

2.4.6 Kitchen Sinks

ASME A112.19.3/CSA B45.4, single compartment, 20 gage stainless steel with integral mounting rim for flush installation, minimum dimensions of 30 inches wide by 21 inches front to rear, with undersides fully sound deadened, with supply openings for use with top mounted washerless sink

faucets with hose spray, and with 3.5 inch drain outlet. Provide aerator with faucet. Water flow rate must not exceed 2.2 gpm when measured at a flowing water pressure of 60 psi. Provide stainless steel drain outlets and stainless steel cup strainers. Provide separate 1.5 inch P-trap and drain piping to vertical vent piping from each compartment. Provide top mounted washerless sink faucets with hose spray.

2.4.7 Service Sinks

ASME A112.19.2/CSA B45.1, white vitreous china ASME A112.19.3/CSA B45.4 302 stainless steel with integral back and wall hanger supports, minimum dimensions of 22 inches wide by 20 inches front to rear, with two supply openings in 10 inch high back. Provide floor supported wall outlet cast iron P-trap and stainless steel rim guards as recommended by service sink manufacturer. Provide back mounted washerless service sink faucets with vacuum breaker and 0.75 inch external hose threads.

2.4.8 Drinking-Water Coolers for Standing Person

ANSI/ASHRAE 18, UL 399, NSF/ANSI 61, ADA and ICC A117.1. Dual or Bi-Level water coolers to conform to the requirements of DRINKING-WATER COOLER FOR STANDING PERSON and WHEELCHAIR DRINKING WATER COOLER conforming to ICC A117.1, ANSI/ASHRAE 18, UL 399, NSF/ANSI 61. Wall mounted height water cooler with more than a single thickness of metal between the potable water and the refrigerant in the heat exchanger, wall-hung, bubbler style, air-cooled condensing unit, 8 gph minimum capacity, stainless steel splash receptor and basin, bottle filler, and stainless steel cabinet. Bubblers must be controlled by push levers or push bars, front mounted or side mounted near the front edge of the cabinet. Bubbler spouts must be mounted at maximum of 38 inches to 43 inches above floor. Spouts must direct water flow at least 4 inches above unit basin and trajectory parallel or nearly parallel to the front of unit. Provide filters for chlorine in supply piping to faucets. Provide ASME A112.6.1M concealed steel pipe chair carriers.

2.4.9 Energy Star Label for Freestanding Bottled Water Coolers/Dispensers

2.4.9.1 Bottleless Water Dispenser

Energy Star Labeled, cold bottleless water dispenser with filters, 0.5 gpm flow rate, floor standing unit. Provide with a cold water temperature of 47 degrees F.

2.4.10 Shower Faucets

Provide ball joint self-cleaning shower heads. Provide WaterSense labeled showerhead with a maximum flow rate of 1.75 gpm. Provide data identifying WaterSense label for showerhead. Fixtures that require the WaterSense label but are located in countries where the label is unavailable, see table below or see <https://uwla.eu/> for WaterSense label substitutes.

WaterSense Equivalencies	
Australia	WELs
Canada	WaterSense

Non-Mandatory Labels*	
European Union	European Water Label
Taiwan	Water Saving Label
China, Hong Kong	WELS

*Water efficiency labels recognized as market transformational, and are recommended, but not required for LEED projects.

2.4.11 Precast Terrazzo Shower Floors

Terrazzo must be made of marble chips cast in white portland cement to produce 3000 psi minimum compressive strength 7 days after casting. Provide floor or wall outlet copper alloy body drain cast integral with terrazzo, with polished stainless steel strainers.

2.4.12 Precast Terrazzo Mop Sinks

Terrazzo must be made of marble chips cast in white portland cement to produce 3000 psi minimum compressive strength 7 days after casting. Terrazzo can include stainless steel curb cap additions with minimum dimensions of 24 inches wide by 24 inches length by 12 inches height. Provide floor or wall outlet copper alloy body drain cast integral with terrazzo, with polished stainless steel strainers.

2.4.13 Emergency Eyewash and Shower

ANSI/ISEA Z358.1, floor supported free standing freeze protected unit with privacy curtain. Provide deluge shower head, stay-open ball valve operated by pull rod and ring or triangular handle. Provide eyewash dust caps and stay-open ball valve operated by foot treadle or push handle. Unit must deliver a minimum of 20 gpm of water at 30 psig flow pressure for 15 minutes. Eye wash unit must have a minimum of 0.4 gpm of water at 30 psig flow pressure for 15 minutes. Position eye wash nozzles 33 inches to 45 inches above finished floor. Provide copper alloy control valves. Provide an air-gap with the lowest potable eye wash water outlet located above the overflow rim by not less than the International Plumbing Code minimum. Provide a pressure-compensated tempering valve, with leaving water temperature setpoint adjustable throughout the range 60 degrees F to 95 degrees F.

2.4.14 Emergency Eye and Face Wash

ANSI/ISEA Z358.1, floor, self-cleaning, nonclogging eye and face wash with quick opening, full-flow valves, dust covers, eye and face wash receptor. Unit must deliver a minimum of 3 gpm of aerated water at 30 psig flow pressure, with eye and face wash nozzles 33 to 45 inches above finished floor. Provide copper alloy control valves. Provide an air-gap with the lowest potable eye and face wash water outlet located above the overflow rim by not less than the International Plumbing Code minimum. Provide a pressure-compensated tempering valve, with leaving water temperature setpoint adjustable throughout the range 60 to 95 degrees F.

2.4.15 Emergency Eyewash

ANSI/ISEA Z358.1, floor, freeze protected, nonclogging eye-wash with quick

opening, full-flow valves, dust covers, eye-wash receptor. Unit must deliver a minimum of 0.4 gpm of water at 30 psig flow pressure, with eye wash nozzles 33 inches to 45 inches above finished floor. Provide copper alloy control valves. Provide an air-gap with the lowest potable eye wash water outlet located above the overflow rim by not less than the International Plumbing Code minimum. Provide a pressure-compensated tempering valve, with leaving water temperature setpoint adjustable throughout the range 60 degrees F to 95 degrees F.

2.5 BACKFLOW PREVENTERS

Backflow prevention devices must be approved by the State or local regulatory agencies. If there is no State or local regulatory agency requirements, the backflow prevention devices must be listed by the Foundation for Cross-Connection Control & Hydraulic Research, or any other approved testing laboratory having equivalent capabilities for both laboratory and field evaluation of backflow prevention devices and assemblies. Reduced pressure principle assemblies, double check valve assemblies, atmospheric (nonpressure) type vacuum breakers, and pressure type vacuum breakers must be meet the above requirements.

Backflow preventers with intermediate atmospheric vent must conform to ASSE 1012. Reduced pressure principle backflow preventers must conform to ASSE 1013. Hose connection vacuum breakers must conform to ASSE 1011. Pipe applied atmospheric type vacuum breakers must conform to ASSE 1001. Pressure vacuum breaker assembly must conform to ASSE 1020. Air gaps in plumbing systems must conform to ASME A112.1.2.

2.6 DRAINS

2.6.1 Floor and Shower Drains

Floor and shower drains must consist of a galvanized body, integral seepage pan, and adjustable perforated or slotted chromium-plated bronze, nickel-bronze, or nickel-brass strainer, consisting of grate and threaded collar. Floor drains must be cast iron except where metallic waterproofing membrane is installed. Drains must be of double drainage pattern for embedding in the floor construction. The seepage pan must have weep holes or channels for drainage to the drainpipe. The seepage pan and weep holes must not be filled or plugged and have pervious materials (such as pea gravel) or a weep hole protection device to allow drainage. The strainer must be adjustable to floor thickness. A clamping device for attaching flashing or waterproofing membrane to the seepage pan without damaging the flashing or waterproofing membrane must be provided when required. Drains must be provided with threaded connection. Between the drain outlet and waste pipe, a neoprene rubber gasket conforming to ASTM C564 may be installed, provided that the drain is specifically designed for the rubber gasket compression type joint. Floor and shower drains must conform to ASME A112.6.3. Provide drain with trap primer connection, trap primer, and connection piping. Primer must meet ASSE 1018.

2.6.1.1 Metallic Shower Pan Drains

Where metallic shower pan membrane is installed, polyethylene drain with corrosion-resistant screws securing the clamping device must be provided. Polyethylene drains must have fittings to adapt drain to waste piping. Polyethylene for floor drains must conform to ASTM D1248. Drains must have separate cast-iron "P" trap, circular body, seepage pan, and strainer, unless otherwise indicated.

2.6.1.2 Drains and Backwater Valves

Drains and backwater valves installed in connection with waterproofed floors or shower pans must be equipped with bolted-type device to securely clamp flashing.

2.6.2 Bathtub and Shower Faucets and Drain Fittings

Provide single control pressure equalizing bathtub and shower faucets with body mounted from behind the wall with threaded connections. Provide ball joint self-cleaning shower heads. Provide WaterSense labeled showerhead with a maximum flow rate of 1.75 gpm. Provide showerheads meeting the requirements in the paragraph SHOWER FAUCETS. Provide tubing mounted from behind the wall between bathtub faucets and shower heads and bathtub diverter spouts. Provide separate globe valves or angle valves with union connections in each supply to faucet. Provide trip-lever pop-up drain fittings for above-the-floor drain installations. The top of drain pop-ups, drain outlets, tub overflow outlet, and; control handle for pop-up drain must be chromium-plated or polished stainless steel. Linkage between drain pop-up and pop-up control handle at bathtub overflow outlet must be copper alloy or stainless steel. Provide 1.5 inch copper alloy adjustable tubing with slip nuts and gaskets between bathtub overflow and drain outlet; chromium-plated finish is not required. Provide bathtub and shower valve with ball type control handle.

2.6.3 Area Drains

Area drains must be plain pattern with polished stainless steel perforated or slotted grate and bottom outlet. The drain must be circular or square with a 12 inch nominal overall width or diameter and 10 inch nominal overall depth. Drains must be cast iron with manufacturer's standard coating. Grate must be easily lifted out for cleaning. Outlet must be suitable for inside caulked connection to drain pipe. Drains must conform to ASME A112.6.3.

2.6.4 Floor Sinks

Floor sinks must be square, with 12 inch nominal overall width or diameter and 10 inch nominal overall depth. Floor sink must have an acid-resistant enamel interior finish with cast-iron body, aluminum sediment bucket, and perforated grate of cast iron in industrial areas and stainless steel in finished areas. The outlet pipe size must be as indicated or of the same size as the connecting pipe.

2.6.5 Boiler Room Drains

Boiler room drains must have combined drain and trap, hinged grate, removable bucket, and threaded brass cleanout with brass backwater valve. The removable galvanized cast-iron sediment bucket must have rounded corners to eliminate fouling and must be equipped with hand grips. Drain must have a minimum water seal of 4 inches. The grate area must be not less than 100 square inches.

2.6.6 Pit Drains

Pit drains must consist of a body, integral seepage pan, and nontilting perforated or slotted grate. Drains must be of double drainage pattern suitable for embedding in the floor construction. The seepage pan must

have weep holes or channels for drainage to the drain pipe. Membrane or flashing clamping device must be provided when required. Drains must be cast iron with manufacturer's standard coating. Drains must be circular and provided with bottom outlet suitable for inside caulked connection, unless otherwise indicated. Drains must be provided with separate cast-iron "P" traps, unless otherwise indicated.

2.6.7 Sight Drains

Sight drains must consist of body, integral seepage pan, and adjustable strainer with perforated or slotted grate and funnel extension. The strainer must have a threaded collar to permit adjustment to floor thickness. Drains must be of double drainage pattern suitable for embedding in the floor construction. A clamping device for attaching flashing or waterproofing membrane to the seepage pan without damaging the flashing or membrane must be provided for other than concrete construction. Drains must have a galvanized heavy cast-iron body and seepage pan and chromium-plated bronze, nickel-bronze, or nickel-brass strainer and funnel combination. Drains must be provided with threaded connection and with a separate cast-iron "P" trap, unless otherwise indicated. Drains must be circular, unless otherwise indicated. The funnel must be securely mounted over an opening in the center of the strainer. Minimum dimensions must be as follows:

Area of strainer and collar: 36 square inches
Height of funnel: 3-3/4 inches
Diameter of lower portion: 2 inches of funnel
Diameter of upper portion: 4 inches of funnel

2.6.8 Roof Drains and Expansion Joints

Roof drains must conform to ASME A112.6.4, with dome and integral flange, and must have a device for making a watertight connection between roofing and flashing. The whole assembly must be galvanized heavy pattern cast iron. For aggregate surface roofing, the drain must be provided with a gravel stop. On roofs other than concrete construction, roof drains must be complete with underdeck clamp, sump receiver, and an extension for the insulation thickness where applicable. A clamping device for attaching flashing or waterproofing membrane to the seepage pan without damaging the flashing or membrane must be provided when required to suit the building construction. Strainer openings must have a combined area equal to twice that of the drain outlet. The outlet must be equipped to make a proper connection to threaded pipe of the same size as the downspout. An expansion joint of proper size to receive the conductor pipe must be provided. The expansion joint must consist of a heavy cast-iron housing, brass or bronze sleeve, brass or bronze fastening bolts and nuts, and gaskets or packing. The sleeve must have a nominal thickness of not less than 0.134 inch. Gaskets and packing must be close-cell neoprene, O-ring packing must be close-cell neoprene of 70 durometer. Packing must be held in place by a packing gland secured with bolts.

2.6.9 Swimming Pool Suction Fittings

Pool water suction fittings in swimming pools must comply with ANSI/APSP-16. The compliance of the fitting must include of the associated drain cover, sump, and hardware. The fitting must be permanently marked to indicate

compliance with the ASME standard, or permanently marked with the symbol "VGB 2008".

2.6.10 Trap Seal Protection

2.6.10.1 Potable Water-Supplied Trap Seal Valve

Trap must be supplied with a source of potable water. The trap seal primer valve must conform to ASSE 1018. The discharge from the valve must connect to the trap seal on the inlet side of the trap.

2.6.10.2 Reclaimed Or Gray Water-Supplied Trap Seal Valve

Trap must be supplied with a source of reclaimed or gray water in accordance with manufacturer of valve. The trap seal primer valve must conform to ASSE 1018. The discharge from the valve must connect to the trap seal on the inlet side of the trap.

2.6.10.3 Waste Water-Supplied Trap Seal Device

Trap will be supplied with a source of waste water conforming to ASSE 1044. The discharge from the device must connect to the trap above the trap seal on the inlet side of the trap.

2.6.10.4 Barrier-Type Trap Seal Protection Device

Trap must be protected with a barrier-type trap seal protection device conforming to ASSE 1072 and must be installed in accordance with the manufacturer's instructions.

2.6.10.5 Electronic Trap Seal Primer

Electronic recessed trap primer consisting of a solenoid valve, vacuum breaker and timer will deliver a timed discharge of water to trap. Provide electronic trap seal primer with ports and hinged access door. ASSE and UL 1951 listed.

2.7 TRAPS

Unless otherwise specified, traps must be copper-alloy adjustable tube type with slip joint inlet and swivel. Traps must be without a cleanout. Provide traps with removable access panels for easy clean-out at sinks and lavatories. Tubes must be copper alloy with walls not less than 0.032 inch thick within commercial tolerances, except on the outside of bends where the thickness may be reduced slightly in manufacture by usual commercial methods. Inlets must have rubber washer and copper alloy nuts for slip joints above the discharge level. Swivel joints must be below the discharge level and must be of metal-to-metal or metal-to-plastic type as required for the application. Nuts must have flats for wrench grip. Outlets must have internal pipe thread, except that when required for the application, the outlets must have sockets for solder-joint connections. The depth of the water seal must be not less than 2 inches. The interior diameter must be not more than 1/8 inch over or under the nominal size, and interior surfaces must be reasonably smooth throughout. A copper alloy "P" trap assembly consisting of an adjustable "P" trap and threaded trap wall nipple with cast brass wall flange must be provided for lavatories. The assembly must be a standard manufactured unit and may have a rubber-gasketed swivel joint.

2.8 INTERCEPTORS

2.8.1 Oil Interceptor

Cast iron or welded steel, coated inside and outside with white acid resistant epoxy, with internal air relief bypass, bronze cleanout plug, double wall trap seal, removable combination pressure equalizing and flow diffusing baffle and sediment bucket, horizontal baffle, adjustable oil draw-off and vent connections on either side, gas and watertight gasketed nonskid cover, and flow control fitting.

2.9 WATER HEATERS

Water heater types and capacities must be as indicated. Each water heater must have replaceable anodes. Each primary water heater must have controls with an adjustable range that includes 90 to 160 degrees F. Each gas-fired water heater and booster water heater must have controls with an adjustable range that includes 120 to 180 degrees F. Hot water systems utilizing recirculation systems must be tied into building off-hour controls. The thermal efficiencies and standby heat losses must conform to TABLE III in PART 3 of this Section for each type of water heater specified. The only exception is that storage water heaters and hot water storage tanks having more than 500 gallons storage capacity need not meet the standard loss requirement if the tank surface area is insulated to R-12.5 and if a standing light is not used. Plastic materials polyetherimide (PEI) and polyethersulfone (PES) are forbidden to be used for vent piping of combustion gases. A factory pre-charged expansion tank must be installed on the cold water supply to each water heater. Expansion tanks must be specifically designed for use on potable water systems and must be rated for 200 degrees F water temperature and 150 psi working pressure. The expansion tank size and acceptance volume must be as indicated.

2.9.1 Automatic Storage Type

Heaters must be complete with control system, temperature gauge, and pressure gauge, and must have ASME rated combination pressure and temperature relief valve.

2.9.1.1 Oil-Fired Type

Oil-fired type water heaters must conform to UL 732.

2.9.1.2 Gas-Fired Type

Gas-fired water heaters must conform to ANSI Z21.10.1/CSA 4.1 when input is 75,000 BTU per hour or less or ANSI Z21.10.3/CSA 4.3 for heaters with input greater than 75,000 BTU per hour. Provide Energy Star labeled gas storage water heater. Provide data identifying Energy Star label for gas storage water heater.

2.9.1.3 Electric Type

Electric type water heaters must conform to UL 174 with dual heating elements. Each element must be 4.5 KW. The elements must be wired so that only one element can operate at a time.

2.9.1.4 Indirect Heater Type

Steam and high temperature hot water (HTHW) heaters with storage system must be the assembled product of one manufacturer, and be ASME tested and "U" stamped to code requirements under ASME BPVC SEC VIII D1. The storage tank must be as specified in paragraph HOT-WATER STORAGE TANKS. The heat exchanger must be double wall type that separates the potable water from the heat transfer medium with a space vented to the atmosphere in accordance with ICC IPC.

- a. HTHW Energy Source: The heater element must have a working pressure of 400 psig with water at a temperature of 400 degrees F. The heating surface must be based on 1 square foot of heating surface to heat 20 gallons or more of water in 1 hour from 40 to 180 degrees F using hot water at a temperature of 350 degrees F. Carbon steel heads must be used. Tubing must conform to ASTM B111/B111M, Copper Alloy No. 706 (90-10 copper-nickel). Heating elements must withstand an internal hydrostatic pressure of 600 psig for not less than 15 seconds without leaking or any evidence of damage.
- b. Steam Energy Source: The heater element must have a working pressure of 150 pounds per square inch gauge (psig) with steam at a temperature of 365 degrees F. The heating surface must be based on 1 square foot of heating surface to heat 20 gallons or more of water in 1 hour from 40 to 180 degrees F using steam at atmospheric pressure. bronze heads must be used. Tubing must be light-drawn copper tubing conforming to ASTM B75/B75M. Heating elements must withstand an internal hydrostatic pressure of 225 psig for not less than 15 seconds without leaking or any evidence of damage.

2.9.2 Instantaneous Water Heater

Heater must be crossflow design with service water in the coil and hot water in the shell. An integral internal controller must be provided, anticipating a change in demand so that the final temperature can be maintained under all normal load conditions when used in conjunction with pilot-operated temperature control system. Normal load conditions must be as specified by the manufacturer for the heater. Unit must be manufactured in accordance with ASME BPVC SEC VIII D1, and must be certified for 150 psi working pressure in the shell and 150 psi working pressure in the coils. Shell must be carbon steel with copper lining. Heads must be carbon steel plate with copper lining. Coils must be copper. Shell must have metal sheathed fiberglass insulation, combination pressure and temperature relief valve, and thermometer. Insulation must be as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. For gas service, provide Energy Star labeled gas instantaneous water heater. Provide data identifying Energy Star label for gas instantaneous water heater.

2.9.3 Electric Instantaneous Water Heaters (Tankless)

UL 499 and UL listed flow switch activated, tankless electric instantaneous water heater for wall mounting below sink or lavatory. Temperature rise at Flow Rate: as indicated on drawings.

2.9.4 Phenolic Resin Coatings for Heater Tubes

The phenolic resin coating system must be applied at either the coil or coating manufacturer's factory in accordance with manufacturer's standard

proven production process. The coating system must be a product specifically intended for use on the material the water heating tubes/coils are made of and must be acceptable for use in potable water systems. The coating system must be capable of withstanding temperatures up to 400 degrees F dry bulb; and meet the requirements of 21 CFR 175.

The entire exterior surface of each coil must be coated with phenolic resin coating system.

2.9.4.1 Standard Product

Provide a phenolic resin coating system that is a standard product of a manufacturer regularly engaged in the manufacturing of products that are of a similar material, design, and workmanship.

Standard products are defined as components and equipment that have been in satisfactory commercial or industrial use in similar applications of similar size for at least 2 years before bid opening. Prior to this 2 year period, these standard products were sold on the commercial market using advertisements in manufacturers' catalogs or brochures. These manufacturers' catalogs, or brochures must have been copyrighted documents or be identified with a manufacturer's document number.

2.9.4.2 Expansion Tank

Provide a ASME potable water expansion tank of steel construction with a NSF/ANSI 61 Butyl diaphragm separating the air chamber from the water containing container. Tank must have a stainless steel inlet connector. Diaphragm must be FDA approved. Maximum operating temperature 200 degrees F, Maximum Working Pressure: 150 PSIG (10.3 bar).

2.10 HOT-WATER STORAGE TANKS

Hot-water storage tanks must be constructed by one manufacturer, ASME stamped for the working pressure, and must have the National Board (ASME) registration. The specification AWWA D100 provides standards for water storage tanks, not domestic hot water storage tanks under domestic water pressure. The statement prior describes the tanks being ASME, it must be ASME BPVC (Boiler and Pressure Vessel Code), stamped for working pressure. The two statements combined describe a hot water storage tank under domestic water pressure. The tank must be cement-lined or glass-lined steel type in accordance with AWWA D100. The heat loss must conform to TABLE III in PART 3 of this Section as determined by the requirements of ASHRAE 90.1 - IP. Each tank must be equipped with a thermometer, conforming to ASTM E1, Type I, Class 3, Range C, style and form as required for the installation, and with 7 inch scale. Thermometer must have a separable socket suitable for a 3/4 inch tapped opening. Tanks must be equipped with a pressure gauge 6 inch minimum diameter face. Insulation must be as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. Storage tank capacity must be as shown. Install hot water storage tanks with access hatches in order to facilitate annual cleaning and inspections.

2.11 PUMPS

2.11.1 Sump Pumps

Sump pumps must be of capacities indicated. The pumps must be of the automatic, electric motor-driven, submerged type, complete with necessary

control equipment and with a split or solid cast-iron or steel cover plate. The pumps must be direct-connected by an approved flexible coupling to a vertical electric motor having a continuous oiling device or packed bearings sealed against dirt and moisture. Motors must be totally enclosed, fan-cooled of sizes as indicated and must be equipped with an across-the-line magnetic controller in a NEMA 250, Type 1 enclosure. Integral size motors must be the premium efficiency type in accordance with NEMA MG 1. Each pump must be fitted with a high-grade thrust bearing mounted above the floor. Each shaft must have an alignment bearing at each end, and the suction inlet must be between 3 and 6 inches above the sump bottom. The suction side of each pump must have a strainer of ample capacity. A float switch assembly, with the switch completely enclosed in a NEMA 250, Type 1 enclosure, must start and stop each motor at predetermined water levels. Duplex pumps must be equipped with an automatic alternator to change the lead operation from one pump to the other, and for starting the second pump if the flow exceeds the capacity of the first pump. The discharge line from each pump must be provided with a union or flange, a nonclog swing check valve, and a stop valve in an accessible location near the pump.

2.11.2 Circulating Pumps

Domestic hot water circulating pumps must be electrically driven, single-stage, centrifugal, with mechanical seals, suitable for the intended service. Pump and motor must be close-coupled with an overhung impeller, or supported by the piping on which it is installed. The shaft must be one-piece, heat-treated, corrosion-resisting steel with impeller and smooth-surfaced housing of bronze.

2.11.2.1 Circulating Pump Enclosure

Motor must be totally enclosed, fan-cooled and must have sufficient horsepower for the service required. Each pump motor must be equipped with an across-the-line magnetic controller in a NEMA 250, Type 1 enclosure with "START-STOP" switch in cover.

2.11.2.2 Circulating Pump Size and Efficiency

Integral size motors must be premium efficiency type in accordance with NEMA MG 1. Pump motors smaller than 1 hp Fractional horsepower pump motors must have integral thermal overload protection in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Guards must shield exposed moving parts.

2.11.3 Booster Pumps

2.11.3.1 Centrifugal Pumps

Horizontal split-case centrifugal-type booster pumps must be furnished. The capacities must be as indicated on drawings, and the speed must not exceed 1800 rpm. Pumps must have a casing of close-grained iron or steel with smooth water passages. A gasket must be provided between the upper and lower halves of the casing. Suction and discharge connections must be flanged. Impellers must be nonoverloading, bronze, balanced to eliminate vibration, and must be keyed to corrosion-resisting steel shafts. The casings must be fitted with bronze wearing or sealing rings. Bearings must be cartridge type, enabling the entire rotating element to be removed without disturbing alignment or exposing the bearings to dirt, water, and other foreign matter. Pumps must be provided with mechanical seals. Seal

boxes must be machined in the pump casing and at both sides of the pump, and must be of sufficient depth to include a conventional bronze seal ring and rows of shaft packing. Bedplates must be close-grain cast iron or steel with ribs and lugs, complete with foundation bolts, and must have a drip lip with drain hole. Each pump must be tested at the manufacturer's plant for operating characteristics at the rated capacity and under specified operating conditions. Test curves must be furnished showing capacity in gpm, head in feet, efficiency, brake horsepower, and operation in parallel with similar pumps. Multiple pump installations must have pump characteristics compatible for operation in parallel with similar pumps. The electric motor must be sized for non-overload when operating at any point along the characteristic curve of the pump. Guards must shield exposed belts and moving parts.

2.11.3.2 Controls

Each pump motor must be provided with enclosed across-the-line-type magnetic controller complete in a NEMA 250 Type 1 enclosure with three position, "HAND-OFF-AUTOMATIC," selector switch in cover. Pumps must be automatically started and stopped by float or pressure switches, as indicated. The pumps must start and stop at the levels and pressures indicated. A multiposition sequence selector switch must be provided so that any two pumps may be operated simultaneously keeping a third pump as a standby.

2.11.4 Flexible Connectors

Flexible connectors must be provided at the suction and discharge of each pump that is 1 hp or larger. Connectors must be constructed of neoprene, rubber, or braided bronze, with Class 150 standard flanges. Flexible connectors must be line size and suitable for the pressure and temperature of the intended service.

2.11.5 Sewage Pumps

Provide single type duplex type with automatic controls to alternate the operation from one pump to the other pump and to start the second pump in the event the first pump cannot handle the incoming flow. Provide high water alarm and check valve.

2.12 WATER PRESSURE BOOSTER SYSTEM

2.12.1 Constant Speed Pumping System

Constant speed pumping system with pressure-regulating valves must employ one lead pump for low flows, and one or more lag pumps for higher flows. Pressure-regulating valves must be provided with nonslam check feature. The factory prepiped and prewired assembly must be mounted on a steel frame, complete with pumps, motors, and automatic controls. The system capacity and capacity of individual pumps must be as indicated. Current sensing relays must provide staging of the pumps. The pumps must be protected from thermal buildup, when running at no-flow, by a common thermal relief valve. Pressure gauges must be mounted on the suction and discharge headers. The control panel must bear the UL listing label for industrial control panels and must be in a NEMA 250, Type 1 enclosure. The control panel must include the following: No-flow shutdown; 7-day time clock; audiovisual alarm; external resets; manual alternation; magnetic motor controllers; time delays; transformer; current relays; "HAND-OFF-AUTOMATIC" switches for each pump; minimum run timers; low

suction pressure cutout; and indicating lights for power on, individual motor overload, and low suction pressure. The control circuit must be interlocked so that the failure of any controller must energize the succeeding controller.

2.12.2 Hydro-Pneumatic Water Pressure System

An ASME code constructed tank stamped for 125 psig water working pressure must be provided. The tank must have a flexible diaphragm made of material conforming to FDA requirements for use with potable water and must be factory precharged to meet required system pressure.

2.12.3 Variable Speed Pumping System

Variable speed pumping system must provide system pressure by varying speed and number of operating pumps. The factory prepiped and prewired assembly must be mounted on a steel frame complete with pumps, variable speed drives, motors, and controls. The variable speed drives must be the oil-filled type capable of power transmission throughout their complete speed range without vibration, noise, or shock loading. Each variable speed drive must be run-tested by the manufacturer for rated performance, and the manufacturer must furnish written performance certification. System must have suppressors to prevent noise transmission over electric feed lines. Required electrical control circuitry and system function sensors must be supplied by the variable speed drive manufacturer. The primary power controls and magnetic motor controllers must be installed in the controls supplied by the drive manufacturer. The sensors must be located in the system to control drive speed as a function of constant pump discharge pressure. Connection between the sensors and the variable speed drive controls must be accomplished with copper wiring. Controls must be in NEMA 250, Type 1 enclosures.

2.13 COMPRESSED AIR SYSTEM

2.13.1 Air Compressors

Air compressor unit must be a factory-packaged assembly, including 3 phase, 480 volt motor controls, switches, wiring, accessories, and motor controllers, in a NEMA 250, Type 1 enclosure. Tank-mounted air compressors must be manufactured to comply with UL listing requirements. Air compressors must have manufacturer's name and address, together with trade name, and catalog number on a nameplate securely attached to the equipment. Each compressor must have a manual-off-automatic switch that when in the manual position, the compressor loads and unloads to meet the demand and, in the automatic position, a time delay relay must allow the compressor to operate for an adjustable length of time unloaded, then stop the unit. Guards must shield exposed moving parts. Each duplex compressor system must be provided with automatic alternation system. Each compressor motor must be provided with an across-the-line-type magnetic controller, complete with low-voltage release. An intake air filter and silencer must be provided with each compressor. Aftercooler and moisture separator must be installed between compressors and air receiver to remove moisture and oil condensate before the air enters the receiver. Aftercoolers must be either air- or water-cooled, as indicated. The air must pass through a sufficient number of tubes to affect cooling. Tubes must be sized to give maximum heat transfer. Water to unit must be controlled by a solenoid or pneumatic valve, which opens when the compressors start and closes when the compressors shut down. Cooling capacity of the aftercooler must be sized for the total capacity

of the compressors. Means must be provided for draining condensed moisture from the receiver by an automatic float type trap. Capacities of air compressors and receivers must be as indicated.

2.13.2 Lubricated Compressors

Compressors must be two-stage, V-belt drive, capable of operating continuously against their designed discharge pressure, and must operate at a speed not in excess of 1800 rpm. Compressors must have the capacity and discharge pressure indicated. Compressors must be assembled complete on a common subbase. The compressor main bearings must be either roller or ball. The discharge passage of the high pressure air must be piped to the air receiver with a copper pipe or tubing. A pressure gauge calibrated to 150 psi and equipped with a gauge cock and pulsation dampener must be furnished for installation adjacent to pressure switches.

2.13.3 Air Receivers

Receivers must be designed for 200 psi working pressure. Receivers must be factory air tested to 1-1/2 times the working pressure. Receivers must be equipped with safety relief valves and accessories, including pressure gauges and automatic and manual drains. The outside of air receivers may be galvanized or supplied with commercial enamel finish. Receivers must be designed and constructed in accordance with ASME BPVC SEC VIII D1 and must have the design working pressures specified herein. A display of the ASME seal on the receiver or a certified test report from an approved independent testing laboratory indicating conformance to the ASME Code must be provided.

2.13.4 Intake Air Supply Filter

Dry type air filter must be provided having a collection efficiency of 99 percent of particles larger than 10 microns. Filter body and media must withstand a maximum 125 psi, capacity as indicated.

2.13.5 Pressure Regulators

The air system must be provided with the necessary regulator valves to maintain the desired pressure for the installed equipment. Regulators must be designed for a maximum inlet pressure of 125 psi and a maximum temperature of 200 degrees F. Regulators must be single-seated, pilot-operated with valve plug, bronze body and trim or equal, and threaded connections. The regulator valve must include a pressure gauge and must be provided with an adjustment screw for adjusting the pressure differential from 0 to 125 psi. Regulator must be sized as indicated.

2.14 DOMESTIC WATER SERVICE METER

The requirements for metering and submetering are specified.

Cold water meters 2 inches and smaller must be positive displacement type conforming to AWWA C700. Cold water meters 2-1/2 inches and larger must be turbine type conforming to AWWA C701. Water meters must be positive displacement, type. Meter register may be round or straight reading type, as provided by the local utility. Meter must be provided with a pulse generator, remote readout register and all necessary wiring and accessories. Meters must be connected to the base wide energy and utility monitoring and control system (if this system exists) using the installation's advanced metering protocols.

2.15 ELECTRICAL WORK

Provide electrical motor driven equipment specified complete with motors, motor starters, and controls as specified herein and in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide internal wiring for components of packaged equipment as an integral part of the equipment. Provide high efficiency type, single-phase, fractional-horsepower alternating-current motors, including motors that are part of a system, corresponding to the applications in accordance with NEMA MG 11. In addition to the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM, provide polyphase, squirrel-cage medium induction motors with continuous ratings, including motors that are part of a system, that meet the efficiency ratings for premium efficiency motors in accordance with NEMA MG 1. Provide motors in accordance with NEMA MG 1 and of sufficient size to drive the load at the specified capacity without exceeding the nameplate rating of the motor.

2.15.1 Electrical Requirements for Motors

Motors must be rated for continuous duty with the enclosure specified. Motor duty requirements must allow for maximum frequency start-stop operation and minimum encountered interval between start and stop. Motor torque must be capable of accelerating the connected load within 20 seconds with 80 percent of the rated voltage maintained at motor terminals during one starting period. Motor bearings must be fitted with grease supply fittings and grease relief to outside of the enclosure.

2.15.2 Electrical Requirements for Controllers and Contactors

Controllers and contactors must have auxiliary contacts for use with the controls provided. Manual or automatic control and protective or signal devices required for the operation specified and any control wiring required for controls and devices specified, but not shown, must be provided. For packaged equipment, the manufacturer must provide controllers, including the required monitors and timed restart.

2.15.3 Electrical Requirements for Power Wiring

Power wiring and conduit for field installed equipment must be provided under and conform to the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.16 MISCELLANEOUS PIPING ITEMS

2.16.1 Escutcheon Plates

Provide one piece or split hinge metal plates for piping entering floors, walls, and ceilings in exposed spaces. Provide chromium-plated on copper alloy plates or polished stainless steel finish in finished spaces. Provide paint finish on plates in unfinished spaces.

2.16.2 Pipe Sleeves

Provide where piping passes entirely through walls, ceilings, roofs, and floors. Sleeves are not required where supply drain, waste, and vent (DWV) piping passes through concrete floor slabs located on grade, except where penetrating a membrane waterproof floor. For multiple pipe penetrations through load bearing masonry or concrete walls, minimum

spacing must be 6 inches center of pipe to center of pipe.

2.16.2.1 Sleeves in Masonry and Concrete

Provide steel pipe sleeves or schedule 40 PVC plastic pipe sleeves. Sleeves are not required where drain, waste, and vent (DWV) piping passes through concrete floor slabs located on grade. Core drilling of masonry and concrete may be provided in lieu of pipe sleeves when cavities in the core-drilled hole are completely grouted smooth.

2.16.2.2 Sleeves Not in Masonry and Concrete

Provide 26 gage galvanized steel sheet or PVC plastic pipe sleeves.

2.16.3 Pipe Hangers (Supports)

Provide MSS SP-58 Type 1 with adjustable type steel support rods, except as specified or indicated otherwise. Attach to steel joists with Type 19 or 23 clamps and retaining straps. Attach to Steel W or S beams with Type 21, 28, 29, or 30 clamps. Attach to steel angles and vertical web steel channels with Type 20 clamp with beam clamp channel adapter. Attach to horizontal web steel channel and wood with drilled hole on centerline and double nut and washer. Attach to concrete with Type 18 insert or drilled expansion anchor. Provide Type 40 insulation protection shield for insulated piping.

2.16.4 Nameplates

Provide 0.125 inch thick melamine laminated plastic nameplates, black matte finish with white center core, for equipment, gages, thermometers, and valves; valves in supplies to faucets will not require nameplates. Accurately align lettering and engrave minimum of 0.25 inch high normal block lettering into the white core. Minimum size of nameplates must be 1.0 by 2.5 inches. Key nameplates to a chart and schedule for each system. Frame charts and schedules under glass and place where directed near each system. Furnish two copies of each chart and schedule.

PART 3 EXECUTION

3.1 GENERAL INSTALLATION REQUIREMENTS

Piping located in air plenums must conform to NFPA 90A requirements. Piping located in shafts that constitute air ducts or that enclose air ducts must be noncombustible in accordance with NFPA 90A. Installation of plastic pipe where in compliance with NFPA may be installed in accordance with PPFA Fire Man. The plumbing system must be installed complete with necessary fixtures, fittings, traps, valves, and accessories. Submit diagrams, instructions, and other sheets proposed for posting for Plumbing System. Submit for Plumbing System manufacturer's recommendations for the installation of bell and spigot and hubless joints for cast iron soil pipe. Water and drainage piping must be extended 5 feet outside the building, unless otherwise indicated. A full port ball valve and drain must be installed on the water service line inside the building approximately 6 inches above the floor from point of entry. Piping must be connected to the exterior service lines or capped or plugged if the exterior service is not in place. Sewer and water pipes must be laid in separate trenches, except when otherwise shown. Exterior underground utilities must be at least 12 inches below the average local frost depth or as indicated on the drawings. If trenches are closed or the pipes are

otherwise covered before being connected to the service lines, the location of the end of each plumbing utility must be marked with a stake or other acceptable means. Valves must be installed with control no lower than the valve body. Avoid the use of combination double wye and one-eighth bend fittings in the horizontal orientation below grade or below slab.

3.1.1 Water Pipe, Fittings, and Connections

3.1.1.1 Utilities

The piping must be extended to fixtures, outlets, and equipment. The hot-water and cold-water piping system must be arranged and installed to permit draining. The supply line to each item of equipment or fixture, except faucets, flush valves, or other control valves which are supplied with integral stops, must be equipped with a shutoff valve to enable isolation of the item for repair and maintenance without interfering with operation of other equipment or fixtures. Supply piping to fixtures, faucets, hydrants, shower heads, and flushing devices must be anchored to prevent movement.

3.1.1.2 Cutting and Repairing

The work must be carefully laid out in advance, and unnecessary cutting of construction must be avoided. Damage to building, piping, wiring, or equipment as a result of cutting must be repaired by mechanics skilled in the trade involved.

3.1.1.3 Protection of Fixtures, Materials, and Equipment

Pipe openings must be closed with caps or plugs during installation. Fixtures and equipment must be tightly covered and protected against dirt, water, chemicals, and mechanical injury. Upon completion of the work, the fixtures, materials, and equipment must be thoroughly cleaned, adjusted, and operated. Safety guards must be provided for exposed rotating equipment.

3.1.1.4 Mains, Branches, and Runouts

Piping must be installed as indicated. Pipe must be accurately cut and worked into place without springing or forcing. Structural portions of the building must not be weakened. Aboveground piping must run parallel with the lines of the building, unless otherwise indicated. Branch pipes from service lines may be taken from top, bottom, or side of main, using crossover fittings required by structural or installation conditions. Supply pipes, valves, and fittings must be kept a sufficient distance from other work and other services to permit not less than 1/2 inch between finished covering on the different services. Bare and insulated water lines must not bear directly against building structural elements so as to transmit sound to the structure or to prevent flexible movement of the lines. Water pipe must not be buried in or under floors unless specifically indicated or approved. Changes in pipe sizes must be made with reducing fittings. Use of bushings will not be permitted except for use in situations in which standard factory fabricated components are furnished to accommodate specific accepted installation practice. Change in direction must be made with fittings, except that bending of pipe 4 inches and smaller will be permitted, provided a pipe bender is used and wide sweep bends are formed. The center-line radius of bends must be not less than six diameters of the pipe. Bent pipe showing kinks, wrinkles,

flattening, or other malformations will not be acceptable.

3.1.1.5 Pipe Drains

Pipe drains indicated must consist of 3/4 inch hose bibb with renewable seat and full port ball valve ahead of hose bibb. At other low points, 3/4 inch brass plugs or caps must be provided. Disconnection of the supply piping at the fixture is an acceptable drain.

3.1.1.6 Expansion and Contraction of Piping

Allowance must be made throughout for expansion and contraction of water pipe. Each hot-water and hot-water circulation riser must have expansion loops or other provisions such as offsets and changes in direction where indicated and required. Risers must be securely anchored as required or where indicated to force expansion to loops. Branch connections from risers must be made with ample swing or offset to avoid undue strain on fittings or short pipe lengths. Horizontal runs of pipe over 50 feet in length must be anchored to the wall or the supporting construction about midway on the run to force expansion, evenly divided, toward the ends. Sufficient flexibility must be provided on branch runouts from mains and risers to provide for expansion and contraction of piping. Flexibility must be provided by installing one or more turns in the line so that piping will spring enough to allow for expansion without straining. If mechanical grooved pipe coupling systems are provided, the deviation from design requirements for expansion and contraction may be allowed pending approval of Contracting Officer.

3.1.1.7 Thrust Restraint

Plugs, caps, tees, valves and bends deflecting 11.25 degrees or more, either vertically or horizontally, in waterlines 4 inches in diameter or larger must be provided with thrust blocks, where indicated, to prevent movement. Thrust blocking must be concrete of a mix not leaner than: 1 cement, 2-1/2 sand, 5 gravel; and having a compressive strength of not less than 2000 psi after 28 days. Blocking must be placed between solid ground and the fitting to be anchored. Unless otherwise indicated or directed on drawings, the base and thrust bearing sides of the thrust block must be poured against undisturbed earth. The side of the thrust block not subject to thrust must be poured against forms. The area of bearing will be as indicated on drawings. Blocking must be placed so that the joints of the fitting are accessible for repair. Steel rods and clamps, protected by galvanizing or by coating with bituminous paint, must be used to anchor vertical down bends into gravity thrust blocks.

3.1.1.8 Commercial-Type Water Hammer Arresters

Commercial-type water hammer arresters must be provided on hot- and cold-water supplies and must be located as generally indicated, with precise location and sizing to be in accordance with PDI WH 201. Water hammer arresters, where concealed, must be accessible by means of access doors or removable panels. Commercial-type water hammer arresters must conform to ASSE 1010. Vertical capped pipe columns will not be permitted.

3.1.2 Compressed Air Piping (Non-Oil Free)

Compressed air piping must have supply lines and discharge terminals legibly and permanently marked at both ends with the name of the system and the direction of flow.

3.1.3 Joints

Installation of pipe and fittings must be made in accordance with the manufacturer's recommendations. Mitering of joints for elbows and notching of straight runs of pipe for tees will not be permitted. Joints must be made up with fittings of compatible material and made for the specific purpose intended.

3.1.3.1 Threaded

Threaded joints must have American Standard taper pipe threads conforming to ASME B1.20.1. Only male pipe threads must be coated with graphite or with an approved graphite compound, or with an inert filler and oil, or must have a polytetrafluoroethylene tape applied.

3.1.3.2 Mechanical Couplings

Mechanical couplings may be used in conjunction with grooved pipe for aboveground, ferrous or non-ferrous, domestic hot and cold water systems, in lieu of unions, brazed, soldered, welded, flanged, or threaded joints.

3.1.3.2.1 Mechanical Coupling Permissibility

Mechanical couplings are permitted in accessible locations including behind access plates. Flexible grooved joints will not be permitted, except as vibration isolators adjacent to mechanical equipment. Rigid grooved joints must incorporate an angle bolt pad design which maintains metal-to-metal contact with equal amount of pad offset of housings upon installation to ensure positive rigid clamping of the pipe. Designs which can only clamp on the bottom of the groove or which utilize gripping teeth or jaws, or which use misaligned housing bolt holes, or which require a torque wrench or torque specifications will not be permitted.

3.1.3.2.2 Grooved Fittings and Couplings

Grooved fittings and couplings, and grooving tools must be provided from the same manufacturer. Segmentally welded elbows must not be used. Grooves must be prepared in accordance with the coupling manufacturer's latest published standards. Grooving must be performed by qualified grooving operators having demonstrated proper grooving procedures in accordance with the tool manufacturer's recommendations. The Contracting Officer must be notified 24 hours in advance of test to demonstrate operator's capability, and the test must be performed at the work site, if practical, or at a site agreed upon. The operator must demonstrate the ability to properly adjust the grooving tool, groove the pipe, and to verify the groove dimensions in accordance with the coupling manufacturer's specifications.

3.1.3.3 Unions and Flanges

Unions, flanges and mechanical couplings must not be concealed in walls, ceilings, or partitions. Unions must be used on pipe sizes 2-1/2 inches and smaller; flanges must be used on pipe sizes 3 inches and larger.

3.1.3.4 Grooved Mechanical Joints

Grooves must be prepared according to the coupling manufacturer's instructions. Grooved fittings, couplings, and grooving tools must be

products of the same manufacturer. Pipe and groove dimensions must comply with the tolerances specified by the coupling manufacturer. The diameter of grooves made in the field must be measured using a "go/no-go" gauge, vernier or dial caliper, narrow-land micrometer, or other method specifically approved by the coupling manufacturer for the intended application. Groove width and dimension of groove from end of pipe must be measured and recorded for each change in grooving tool setup to verify compliance with coupling manufacturer's tolerances. Grooved joints must not be used in concealed locations.

3.1.3.5 Cast Iron Soil, Waste and Vent Pipe

Bell and spigot compression and hubless gasketed clamp joints for soil, waste and vent piping must be installed per the manufacturer's recommendations.

3.1.3.6 Copper Tube and Pipe

- a. Brazed. Brazed joints must be made in conformance with AWS B2.2/B2.2M, ASME B16.50, and CDA A4015 with flux and are acceptable for all pipe sizes. Copper to copper joints must include the use of copper-phosphorus or copper-phosphorus-silver brazing metal without flux. Brazing of dissimilar metals (copper to bronze or brass) must include the use of flux with either a copper-phosphorus, copper-phosphorus-silver or a silver brazing filler metal.
- b. Soldered. Soldered joints must be made with flux and are only acceptable for piping 2 inches and smaller. Soldered joints must conform to ASME B31.5 and CDA A4015. Soldered joints must not be used in compressed air piping between the air compressor and the receiver.
- c. Copper Tube Extracted Joint. Mechanically extracted joints must be made in accordance with ICC IPC.
- d. Press connection. Copper press connections must be made in **strict** accordance with the manufacturer's installation instructions for manufactured rated size. The joints must be pressed using the tool(s) approved by the manufacturer **of that joint**. Minimum distance between fittings must be in accordance with the manufacturer's requirements.

3.1.3.7 Plastic Pipe

Acrylonitrile-Butadiene-Styrene (ABS) pipe must have joints made with solvent cement. PVC and CPVC pipe must have joints made with solvent cement elastomeric, threading, (threading of Schedule 80 Pipe is allowed only where required for disconnection and inspection; threading of Schedule 40 Pipe is not allowed), or mated flanged.

3.1.3.8 Glass Pipe

Joints for corrosive waste glass pipe and fittings must be made with corrosion-resisting steel compression-type couplings with acrylonitrile rubber gaskets lined with polytetrafluoroethylene.

3.1.3.9 Corrosive Waste Plastic Pipe

Joints for polyolefin pipe and fittings must be made by mechanical joint or electrical fusion coil method in accordance with ASTM D2657 and ASTM F1290. Joints for filament-wound reinforced thermosetting resin pipe

must be made in accordance with manufacturer's instructions. Unions or flanges must be used where required for disconnection and inspection.

3.1.3.10 Polypropylene Pipe

Joints for polypropylene pipe and fittings must be made by heat fusion welding socket-type or butt-fusion type fittings and must comply with ASTM F2389.

3.1.4 Dissimilar Pipe Materials

Connections between ferrous and non-ferrous copper water pipe must be made with dielectric unions or flange waterways. Dielectric waterways must have temperature and pressure rating equal to or greater than that specified for the connecting piping. Waterways must have metal connections on both ends suited to match connecting piping. Dielectric waterways must be internally lined with an insulator specifically designed to prevent current flow between dissimilar metals. Dielectric flanges must meet the performance requirements described herein for dielectric waterways. Connecting joints between plastic and metallic pipe must be made with transition fitting for the specific purpose.

3.1.5 Corrosion Protection for Buried Pipe and Fittings

Ductile iron, cast iron, and steel pipe, fittings, and joints must have a protective coating. Additionally, ductile iron, cast iron, and steel pressure pipe must have a cathodic protection system and joint bonding. The cathodic protection system, protective coating system, and joint bonding for cathodically protected pipe. Coatings must be selected, applied, and inspected in accordance with NACE SP0169 and as otherwise specified. The pipe must be cleaned and the coating system applied prior to pipe tightness testing. Joints and fittings must be cleaned and the coating system applied after pipe tightness testing. For tape coating systems, the tape must conform to AWWA C203 and must be applied with a 50 percent overlap. Primer utilized with tape type coating systems must be as recommended by the tape manufacturer.

3.1.6 Pipe Sleeves and Flashing

Pipe sleeves must be furnished and set in their proper and permanent location.

3.1.6.1 Sleeve Requirements

Unless indicated otherwise, provide pipe sleeves meeting the following requirements:

- a. Secure sleeves in position and location during construction. Provide sleeves of sufficient length to pass through entire thickness of walls, ceilings, roofs, and floors.
- b. A modular mechanical type sealing assembly may be installed in lieu of a waterproofing clamping flange and caulking and sealing of annular space between pipe and sleeve. The seals must consist of interlocking synthetic rubber links shaped to continuously fill the annular space between the pipe and sleeve using galvanized steel bolts, nuts, and pressure plates. The links must be loosely assembled with bolts to form a continuous rubber belt around the pipe with a pressure plate under each bolt head and each nut. After the seal assembly is

properly positioned in the sleeve, tightening of the bolt must cause the rubber sealing elements to expand and provide a watertight seal between the pipe and the sleeve. Each seal assembly must be sized as recommended by the manufacturer to fit the pipe and sleeve involved.

- c. Sleeves must not be installed in structural members, except where indicated or approved. Rectangular and square openings must be as detailed. Each sleeve must extend through its respective floor, or roof, and must be cut flush with each surface, except for special circumstances. Pipe sleeves passing through floors in wet areas such as mechanical equipment rooms, lavatories, kitchens, and other plumbing fixture areas must extend a minimum of 4 inches above the finished floor.
- d. Unless otherwise indicated, sleeves must be of a size to provide a minimum of 1 inch clearance between bare pipe or insulation and inside of sleeve or between insulation and inside of sleeve. Sleeves in bearing walls and concrete slab on grade floors must be steel pipe or cast-iron pipe. Sleeves in nonbearing walls or ceilings may be steel pipe, cast-iron pipe, galvanized sheet metal with lock-type longitudinal seam, or plastic.
- e. Except as otherwise specified, the annular space between pipe and sleeve, or between jacket over insulation and sleeve, must be sealed as indicated with sealants conforming to ASTM C920 and with a primer, backstop material and surface preparation as specified in Section 07 92 00 JOINT SEALANTS. The annular space between pipe and sleeve, between bare insulation and sleeve or between jacket over insulation and sleeve must not be sealed for interior walls which are not designated as fire rated.
- f. Sleeves through below-grade walls in contact with earth must be recessed 1/2 inch from wall surfaces on both sides. Annular space between pipe and sleeve must be filled with backing material and sealants in the joint between the pipe and concrete wall as specified above. Sealant selected for the earth side of the wall must be compatible with dampproofing/waterproofing materials that are to be applied over the joint sealant. Pipe sleeves in fire-rated walls must conform to the requirements in Section 07 84 00 FIRESTOPPING.

3.1.1.6.2 Flashing Requirements

Pipes passing through roof must be installed through a 16 ounce copper flashing, each within an integral skirt or flange. Flashing must be suitably formed, and the skirt or flange must extend not less than 8 inches from the pipe and must be set over the roof or floor membrane in a solid coating of bituminous cement. The flashing must extend up the pipe a minimum of 10 inches. For cleanouts, the flashing must be turned down into the hub and caulked after placing the ferrule. Pipes passing through pitched roofs must be flashed, using lead or copper flashing, with an adjustable integral flange of adequate size to extend not less than 8 inches from the pipe in all directions and lapped into the roofing to provide a watertight seal. The annular space between the flashing and the bare pipe or between the flashing and the metal-jacket-covered insulation must be sealed as indicated. Flashing for dry vents must be turned down into the pipe to form a waterproof joint. Pipes, up to and including 10 inches in diameter, passing through roof or floor waterproofing membrane may be installed through a cast-iron sleeve with caulking recess, anchor lugs, flashing-clamp device, and pressure ring with brass bolts. Flashing

shield must be fitted into the sleeve clamping device. Pipes passing through wall waterproofing membrane must be sleeved as described above. A waterproofing clamping flange must be installed.

3.1.6.3 Waterproofing

Waterproofing at floor-mounted water closets must be accomplished by forming a flashing guard from soft-tempered sheet copper. The center of the sheet must be perforated and turned down approximately 1-1/2 inches to fit between the outside diameter of the drainpipe and the inside diameter of the cast-iron or steel pipe sleeve. The turned-down portion of the flashing guard must be embedded in sealant to a depth of approximately 1-1/2 inches; then the sealant must be finished off flush to floor level between the flashing guard and drainpipe. The flashing guard of sheet copper must extend not less than 8 inches from the drainpipe and must be lapped between the floor membrane in a solid coating of bituminous cement. If cast-iron water closet floor flanges are used, the space between the pipe sleeve and drainpipe must be sealed with sealant and the flashing guard must be upturned approximately 1-1/2 inches to fit the outside diameter of the drainpipe and the inside diameter of the water closet floor flange. The upturned portion of the sheet fitted into the floor flange must be sealed.

3.1.6.4 Optional Counterflashing

Instead of turning the flashing down into a dry vent pipe, or caulking and sealing the annular space between the pipe and flashing or metal-jacket-covered insulation and flashing, counterflashing may be accomplished by utilizing the following:

- a. A standard roof coupling for threaded pipe up to 6 inches in diameter.
- b. A tack-welded or banded-metal rain shield around the pipe.

3.1.6.5 Pipe Penetrations of Slab on Grade Floors

Where pipes, fixture drains, floor drains, cleanouts or similar items penetrate slab on grade floors, except at penetrations of floors with waterproofing membrane as specified in paragraphs FLASHING REQUIREMENTS and WATERPROOFING, a groove 1/4 to 1/2 inch wide by 1/4 to 3/8 inch deep must be formed around the pipe, fitting or drain. The groove must be filled with a sealant as specified in Section 07 92 00 JOINT SEALANTS.

3.1.6.6 Pipe Penetrations

Provide sealants for all pipe penetrations. All pipe penetrations must be sealed to prevent infiltration of air, insects, and vermin.

3.1.7 Fire Seal

Where pipes pass through fire walls, fire-partitions, fire-rated pipe chase walls or floors above grade, a fire seal must be provided as specified in Section 07 84 00 FIRESTOPPING.

3.1.8 Supports

3.1.8.1 General

Hangers used to support piping 2 inches and larger must be fabricated to

permit adequate adjustment after erection while still supporting the load. Pipe guides and anchors must be installed to keep pipes in accurate alignment, to direct the expansion movement, and to prevent buckling, swaying, and undue strain. Piping subjected to vertical movement when operating temperatures exceed ambient temperatures must be supported by variable spring hangers and supports or by constant support hangers. In the support of multiple pipe runs on a common base member, a clip or clamp must be used where each pipe crosses the base support member. Spacing of the base support members must not exceed the hanger and support spacing required for an individual pipe in the multiple pipe run. Threaded sections of rods must not be formed or bent.

3.1.8.2 Pipe Supports and Structural Bracing, Seismic Requirements

Piping and attached valves must be supported and braced to resist seismic loads. Structural steel required for reinforcement to properly support piping, headers, and equipment, but not shown, must be provided. Material used for supports must be as specified in Section 05 12 00 STRUCTURAL STEEL.

3.1.8.3 Pipe Hangers, Inserts, and Supports

Installation of pipe hangers, inserts and supports must conform to MSS SP-58 except as modified herein.

- a. Types 5, 12, and 26 must not be used.
- b. Type 3 must not be used on insulated pipe.
- c. Type 18 inserts must be secured to concrete forms before concrete is placed. Continuous inserts which allow more adjustment may be used if they otherwise meet the requirements for type 18 inserts.
- d. Type 19 and 23 C-clamps must be torqued per MSS SP-58 and must have both locknuts and retaining devices furnished by the manufacturer. Field-fabricated C-clamp bodies or retaining devices are not acceptable.
- e. Type 20 attachments used on angles and channels must be furnished with an added malleable-iron heel plate or adapter.
- f. Type 24 may be used only on trapeze hanger systems or on fabricated frames.
- g. Type 39 saddles must be used on insulated pipe 4 inches and larger when the temperature of the medium is 60 degrees F or higher. Type 39 saddles must be welded to the pipe.
- h. Type 40 shields must:
 - (1) Be used on insulated pipe less than 4 inches.
 - (2) Be used on insulated pipe 4 inches and larger when the temperature of the medium is 60 degrees F or less.
 - (3) Have a high density insert for all pipe sizes. High density inserts must have a density of 8 pcf or greater.
- i. Horizontal pipe supports must be spaced as specified in MSS SP-58 and a support must be installed not over 1 foot from the pipe fitting

joint at each change in direction of the piping. Pipe supports must be spaced not over 5 feet apart at valves. Operating temperatures in determining hanger spacing for PVC or CPVC pipe must be 120 degrees F for PVC and 180 degrees F for CPVC. Horizontal pipe runs must include allowances for expansion and contraction.

- j. Vertical pipe must be supported at each floor, except at slab-on-grade, at intervals of not more than 15 feet nor more than 8 feet from end of risers, and at vent terminations. Vertical pipe risers must include allowances for expansion and contraction.
- k. Type 35 guides using steel, reinforced polytetrafluoroethylene (PTFE) or graphite slides must be provided to allow longitudinal pipe movement. Slide materials must be suitable for the system operating temperatures, atmospheric conditions, and bearing loads encountered. Lateral restraints must be provided as needed. Where steel slides do not require provisions for lateral restraint the following may be used:
 - (1) On pipe 4 inches and larger when the temperature of the medium is 60 degrees F or higher, a Type 39 saddle, welded to the pipe, may freely rest on a steel plate.
 - (2) On pipe less than 4 inches a Type 40 shield, attached to the pipe or insulation, may freely rest on a steel plate.
 - (3) On pipe 4 inches and larger carrying medium less than 60 degrees F a Type 40 shield, attached to the pipe or insulation, may freely rest on a steel plate.
- l. Pipe hangers on horizontal insulated pipe must be the size of the outside diameter of the insulation. The insulation must be continuous through the hanger on all pipe sizes and applications.
- m. Where there are high system temperatures and welding to piping is not desirable, the type 35 guide must include a pipe cradle, welded to the guide structure and strapped securely to the pipe. The pipe must be separated from the slide material by at least 4 inches or by an amount adequate for the insulation, whichever is greater.
- n. Hangers and supports for plastic pipe must not compress, distort, cut or abrade the piping, and must allow free movement of pipe except where otherwise required in the control of expansion/contraction.

3.1.8.4 Structural Attachments

Attachment to building structure concrete and masonry must be by cast-in concrete inserts, built-in anchors, or masonry anchor devices. Inserts and anchors must be applied with a safety factor not less than 5. Supports must not be attached to metal decking. Supports must not be attached to the underside of concrete filled floor or concrete roof decks unless approved by the Contracting Officer. Masonry anchors for overhead applications must be constructed of ferrous materials only.

3.1.9 Welded Installation

Plumbing pipe weldments must be as indicated. Changes in direction of piping must be made with welding fittings only; mitering or notching pipe to form elbows and tees or other similar type construction will not be permitted. Branch connection may be made with either welding tees or

forged branch outlet fittings. Branch outlet fittings must be forged, flared for improvement of flow where attached to the run, and reinforced against external strains. Beveling, alignment, heat treatment, and inspection of weld must conform to ASME B31.1. Weld defects must be removed and repairs made to the weld, or the weld joints must be entirely removed and rewelded. After filler metal has been removed from its original package, it must be protected or stored so that its characteristics or welding properties are not affected. Electrodes that have been wetted or that have lost any of their coating must not be used.

3.1.10 Pipe Cleanouts

Pipe cleanouts must be the same size as the pipe except that cleanout plugs larger than 4 inches will not be required. A cleanout installed in connection with cast-iron soil pipe must consist of a long-sweep 1/4 bend or one or two 1/8 bends extended to the place shown. An extra-heavy cast-brass or cast-iron ferrule with countersunk cast-brass head screw plug must be caulked into the hub of the fitting and must be flush with the floor. Cleanouts in connection with other pipe, where indicated, must be T-pattern, 90-degree branch drainage fittings with cast-brass screw plugs, except plastic plugs must be installed in plastic pipe. Plugs must be the same size as the pipe up to and including 4 inches. Cleanout tee branches with screw plug must be installed at the foot of soil and waste stacks, at the foot of interior downspouts, on each connection to building storm drain where interior downspouts are indicated, and on each building drain outside the building. Cleanout tee branches may be omitted on stacks in single story buildings with slab-on-grade construction or where less than 18 inches of crawl space is provided under the floor. Cleanouts on pipe concealed in partitions must be provided with chromium plated bronze, nickel bronze, nickel brass or stainless steel flush type access cover plates. Round access covers must be provided and secured to plugs with securing screw. Square access covers may be provided with matching frames, anchoring lugs and cover screws. Cleanouts in finished walls must have access covers and frames installed flush with the finished wall. Cleanouts installed in finished floors subject to foot traffic must be provided with a chrome-plated cast brass, nickel brass, or nickel bronze cover secured to the plug or cover frame and set flush with the finished floor. Heads of fastening screws must not project above the cover surface. Where cleanouts are provided with adjustable heads, the heads must be cast iron.

3.1.11 Condensate Drain Piping for Tropical Environments

Condensate drain piping materials must be rated for Drain, Waste and Vent service. Above grade use Copper Type DWV ASTM B306. Condensate piping must maintain a horizontal slope in the direction of discharge of not less than one-eighth unit vertical in 12 units horizontal (1 percent). Do not use PVC above grade in mechanical rooms, fire riser rooms, generator rooms or other high-abuse areas. The following condensate pipe diameters must be sized in accordance with equipment capacity refrigeration shown below:

EQUIPMENT CAPACITY	MINIMUM CONDENSATE PIPE DIAMETER
Up to 5 tons	1 inch
Over 5 tons to 40 tons	1-1/4 inch

EQUIPMENT CAPACITY	MINIMUM CONDENSATE PIPE DIAMETER
Over 40 tons to 90 tons	1-1/2 inch
Over 90 tons to 125 tons	2 inch
Over 125 tons to 250 tons of refrigeration	2-1/2 inch

3.2 WATER HEATERS AND HOT WATER STORAGE TANKS

3.2.1 Relief Valves

No valves must be installed between a relief valve and its water heater or storage tank. The P&T relief valve must be installed where the valve actuator comes in contact with the hottest water in the heater. Whenever possible, the relief valve must be installed directly in a tapping in the tank or heater; otherwise, the P&T valve must be installed in the hot-water outlet piping. A vacuum relief valve must be provided on the cold water supply line to the hot-water storage tank or water heater and mounted above and within 6 inches above the top of the tank or water heater.

3.2.2 Installation of Gas- and Oil-Fired Water Heater

Installation must conform to NFPA 54 for gas fired and NFPA 31 for oil fired. Storage water heaters that are not equipped with integral heat traps and having vertical pipe risers must be installed with heat traps directly on both the inlet and outlet. Circulating systems need not have heat traps installed. An acceptable heat trap may be a piping arrangement such as elbows connected so that the inlet and outlet piping make vertically upward runs of not less than 24 inches just before turning downward or directly horizontal into the water heater's inlet and outlet fittings. Commercially available heat traps, specifically designed by the manufacturer for the purpose of effectively restricting the natural tendency of hot water to rise through vertical inlet and outlet piping during standby periods may also be approved.

3.2.3 Heat Traps

Piping to and from each water heater and hot water storage tank must be routed horizontally and downward a minimum of 24 inches before turning in an upward direction.

3.2.4 Connections to Water Heaters

Connections of metallic pipe to water heaters must be made with dielectric unions or flanges. Use of dielectric nipples is prohibited unless internally lined and specifically designed to limit current flow between dissimilar metals.

3.2.5 Expansion Tank

A pre-charged expansion tank must be installed on the cold water supply between the water heater inlet and the cold water supply shut-off valve. The Contractor must adjust the expansion tank air pressure, as recommended by the tank manufacturer, to match incoming water pressure.

3.3 FIXTURES AND FIXTURE TRIMMINGS

Polished chromium-plated pipe, valves, and fittings must be provided where exposed to view. Angle stops, straight stops, stops integral with the faucets, or concealed type of lock-shield, and loose-key pattern stops for supplies with threaded, sweat or solvent weld inlets must be furnished and installed with fixtures. Where connections between copper tubing and faucets are made by rubber compression fittings, a beading tool must be used to mechanically deform the tubing above the compression fitting. Exposed traps and supply pipes for fixtures and equipment must be connected to the rough piping systems at the wall, unless otherwise specified under the item. Floor and wall escutcheons must be as specified. Drain lines and hot water lines of fixtures for handicapped personnel must be insulated and do not require polished chrome finish. Plumbing fixtures and accessories must be installed within the space shown.

3.3.1 Fixture Connections

Where space limitations prohibit standard fittings in conjunction with the cast-iron floor flange, special short-radius fittings must be provided. Connections between earthenware fixtures and flanges on soil pipe must be made gastight and watertight with a closet-setting compound or neoprene gasket and seal. Use of natural rubber gaskets or putty will not be permitted. Fixtures with outlet flanges must be set the proper distance from floor or wall to make a first-class joint with the closet-setting compound or gasket and fixture used.

3.3.2 Flushometer Valves

Flushometer valves must be secured to prevent movement by anchoring the long finished top spud connecting tube to wall adjacent to valve with approved metal bracket. Flushometer valves for water closets must be installed 39 inches above the floor, except at water closets intended for use by the physically handicapped where flushometer valves must be mounted at approximately 30 inches above the floor and arranged to avoid interference with grab bars. In addition, for water closets intended for handicap use, the flush valve handle must be installed on the wide side of the enclosure.

3.3.3 Height of Fixture Rims Above Floor

Lavatories must be mounted with rim 31 inches above finished floor. Wall-hung drinking fountains and water coolers must be installed with rim 42 inches above floor. Wall-hung service sinks must be mounted with rim 28 inches above the floor. Installation of fixtures for use by the physically handicapped must be in accordance with ICC A117.1.

3.3.4 Shower Bath Outfits

The area around the water supply piping to the mixing valves and behind the escutcheon plate must be made watertight by caulking or gasketing.

3.3.5 Fixture Supports

Fixture supports for off-the-floor lavatories, urinals, water closets, and other fixtures of similar size, design, and use, must be of the chair-carrier type. The carrier must provide the necessary means of mounting the fixture, with a foot or feet to anchor the assembly to the floor slab. Adjustability must be provided to locate the fixture at the

desired height and in proper relation to the wall. Support plates, in lieu of chair carrier, must be fastened to the wall structure only where it is not possible to anchor a floor-mounted chair carrier to the floor slab.

3.3.5.1 Support for Solid Masonry Construction

Chair carrier must be anchored to the floor slab. Where a floor-anchored chair carrier cannot be used, a suitable wall plate must be imbedded in the masonry wall.

3.3.5.2 Support for Concrete-Masonry Wall Construction

Chair carrier must be anchored to floor slab. Where a floor-anchored chair carrier cannot be used, a suitable wall plate must be fastened to the concrete wall using through bolts and a back-up plate.

3.3.5.3 Support for Steel Stud Frame Partitions

Chair carrier must be used. The anchor feet and tubular uprights must be of the heavy duty design; and feet (bases) must be steel and welded to a square or rectangular steel tube upright. Wall plates, in lieu of floor-anchored chair carriers, must be used only if adjoining steel partition studs are suitably reinforced to support a wall plate bolted to these studs.

3.3.5.4 Support for Wood Stud Construction

Where floor is a concrete slab, a floor-anchored chair carrier must be used. Where entire construction is wood, wood crosspieces must be installed. Fixture hanger plates, supports, brackets, or mounting lugs must be fastened with not less than No. 10 wood screws, 1/4 inch thick minimum steel hanger, or toggle bolts with nut. The wood crosspieces must extend the full width of the fixture and must be securely supported.

3.3.5.5 Wall-Mounted Water Closet Gaskets

Where wall-mounted water closets are provided, reinforced wax, treated felt, or neoprene gaskets must be provided. The type of gasket furnished must be as recommended by the chair-carrier manufacturer.

3.3.6 Backflow Prevention Devices

Plumbing fixtures, equipment, and pipe connections must not cross connect or interconnect between a potable water supply and any source of nonpotable water. Backflow preventers must be installed where indicated and in accordance with IAPMO UPC at all other locations necessary to preclude a cross-connect or interconnect between a potable water supply and any nonpotable substance. In addition backflow preventers must be installed at all locations where the potable water outlet is below the flood level of the equipment, or where the potable water outlet will be located below the level of the nonpotable substance. Backflow preventers must be located so that no part of the device will be submerged. Backflow preventers must be of sufficient size to allow unrestricted flow of water to the equipment, and preclude the backflow of any nonpotable substance into the potable water system. Bypass piping must not be provided around backflow preventers. Access must be provided for maintenance and testing. Each device must be a standard commercial unit.

3.3.7 Access Panels

Access panels must be provided for concealed valves and controls, or any item requiring inspection or maintenance. Access panels must be of sufficient size and located so that the concealed items may be serviced, maintained, or replaced. Access panels must be as specified in Section 08 31 00 ACCESS DOORS AND PANELS.

3.3.8 Sight Drains

Sight drains must be installed so that the indirect waste will terminate 2 inches above the flood rim of the funnel to provide an acceptable air gap.

3.3.9 Traps

Each trap must be placed as near the fixture as possible, and no fixture must be double-trapped. Traps installed on cast-iron soil pipe must be cast iron. Traps installed on steel pipe or copper tubing must be recess-drainage pattern, or brass-tube type. Traps installed on plastic pipe may be plastic conforming to ASTM D3311. Traps for acid-resisting waste must be of the same material as the pipe.

3.3.10 Shower Pans

Before installing shower pan, subfloor must be free of projections such as nail heads or rough edges of aggregate. Drain must be a bolt-down, clamping-ring type with weepholes, installed so the lip of the subdrain is flush with subfloor.

3.3.10.1 General

The floor of each individual shower, the shower-area portion of combination shower and drying room, and the entire shower and drying room where the two are not separated by curb or partition, must be made watertight with a shower pan fabricated in place. The shower pan material must be cut to size and shape of the area indicated, in one piece to the maximum extent practicable, allowing a minimum of 6 inches for turnup on walls or partitions, and must be folded over the curb with an approximate return of 1/4 of curb height. The upstands must be placed behind any wall or partition finish. Subflooring must be smooth and clean, with nailheads driven flush with surface, and must be sloped to drain. Shower pans must be clamped to drains with the drain clamping ring.

3.3.10.2 Metal Shower Pans

When a shower pan of required size cannot be furnished in one piece, metal pieces must be joined with a flintlock seam and soldered or burned. The corners must be folded, not cut, and the corner seam must be soldered or burned. Pans, including upstands, must be coated on all surfaces with one brush coat of asphalt. Asphalt must be applied evenly at not less than 1 gallon per 50 square feet. A layer of felt covered with building paper must be placed between shower pans and wood floors. The joining surfaces of metal pan and drain must be given a brush coat of asphalt after the pan is connected to the drain.

3.3.10.3 Plasticized Chlorinated Polyethylene Shower Pans

Corners of plasticized chlorinated polyethylene shower pans must be folded against the upstand by making a pig-ear fold. Hot-air gun or heat lamp

must be used in making corner folds. Each pig-ear corner fold must be nailed or stapled 1/2 inch from the upper edge to hold it in place. Nails must be galvanized large-head roofing nails. On metal framing or studs, approved duct tape must be used to secure pig-ear fold and membrane. Where no backing is provided between the studs, the membrane slack must be taken up by pleating and stapling or nailing to studding 1/2 inch from upper edge. To adhere the membrane to vertical surfaces, the back of the membrane and the surface to which it will be applied must be coated with adhesive that becomes dry to the touch in 5 to 10 minutes, after which the membrane must be pressed into place. Surfaces to be solvent-welded must be clean. Surfaces to be joined with xylene must be initially sprayed and vigorously cleaned with a cotton cloth, followed by final coating of xylene and the joining of the surfaces by roller or equivalent means. If ambient or membrane temperatures are below 40 degrees F the membrane and the joint must be heated prior to application of xylene. Heat may be applied with hot-air gun or heat lamp, taking precautions not to scorch the membrane. Adequate ventilation and wearing of gloves are required when working with xylene. Membrane must be pressed into position on the drain body, and must be cut and fit to match so that membrane can be properly clamped and an effective gasket-type seal provided. On wood subflooring, two layers of 15 pound dry felt must be installed prior to installation of shower pan to ensure a smooth surface for installation.

3.3.10.4 Nonplasticized Polyvinyl Chloride (PVC) Shower Pans

Nonplasticized PVC must be turned up behind walls or wall surfaces a distance of not less than 6 inches in room areas and 3 inches above curb level in curbed spaces with sufficient material to fold over and fasten to outside face of curb. Corners must be pig-ear type and folded between pan and studs. Only top 1 inch of upstand must be nailed to hold in place. Nails must be galvanized large-head roofing type. Approved duct tape must be used on metal framing or studs to secure pig-ear fold and membrane. Where no backing is provided between studs, the membrane slack must be taken up by pleating and stapling or nailing to studding at top inch of upstand. To adhere the membrane to vertical surfaces, the back of the membrane and the surface to which it is to be applied must be coated with adhesive that becomes dry to the touch in 5 to 10 minutes, after which the membrane must be pressed into place. Trim for drain must be exactly the size of drain opening. Bolt holes must be pierced to accommodate bolts with a tight fit. Adhesive must be used between pan and subdrain. Clamping ring must be bolted firmly. A small amount of gravel or porous materials must be placed at weepholes so that holes remain clear when setting bed is poured. Membrane must be solvent welded with PVC solvent cement. Surfaces to be solvent welded must be clean (free of grease and grime). Sheets must be laid on a flat surface with an overlap of about 2 inches. Top edge must be folded back and surface primed with a PVC primer. PVC cement must be applied and surfaces immediately placed together, while still wet. Joint must be lightly rolled with a paint roller, then as the joint sets must be rolled firmly but not so hard as to distort the material. In long lengths, about 2 or 3 feet at a time must be welded. On wood subflooring, two layers of 15 pound felt must be installed prior to installation of shower pan to ensure a smooth surface installation.

3.4 VIBRATION-ABSORBING FEATURES

Mechanical equipment, including compressors and pumps, must be isolated from the building structure by approved vibration-absorbing features, unless otherwise shown. Submit details of vibration-absorbing features,

including arrangement, foundation plan, dimensions and specifications. Each foundation must include an adequate number of standard isolation units. Each unit must consist of machine and floor or foundation fastening, together with intermediate isolation material, and must be a standard product with printed load rating. Piping connected to mechanical equipment must be provided with flexible connectors. Isolation unit installation must limit vibration to percent of the lowest equipment rpm.

3.4.1 Tank- or Skid-Mounted Compressors

Floor attachment must be as recommended by compressor manufacturer.

3.4.2 Foundation-Mounted Compressors

Foundation attachment must be as recommended by the compressor manufacturer.

3.5 WATER METER REMOTE READOUT REGISTER

The remote readout register must be mounted at the location indicated or as directed by the Contracting Officer.

3.6 IDENTIFICATION SYSTEMS

3.6.1 Identification Tags

Identification tags made of brass, engraved laminated plastic, or engraved anodized aluminum, indicating service and valve number must be installed on valves, except those valves installed on supplies at plumbing fixtures. Tags must be 1-3/8 inch minimum diameter, and marking must be stamped or engraved. Indentations must be black, for reading clarity. Tags must be attached to valves with No. 12 AWG, copper wire, chrome-plated beaded chain, or plastic straps designed for that purpose.

3.6.2 Pipe Color Code Marking

Color code marking of piping must be as specified in Section 09 90 00 PAINTS AND COATINGS.

3.6.3 Color Coding Scheme for Locating Hidden Utility Components

Scheme must be provided in buildings having suspended grid ceilings. The color coding scheme must identify points of access for maintenance and operation of operable components which are not visible from the finished space and installed in the space directly above the suspended grid ceiling. The operable components must include valves, dampers, switches, linkages and thermostats. The color coding scheme must consist of a color code board and colored metal disks. Each colored metal disk must be approximately 3/8 inch in diameter and secured to removable ceiling panels with fasteners. The fasteners must be inserted into the ceiling panels so that the fasteners will be concealed from view. The fasteners must be manually removable without tools and must not separate from the ceiling panels when panels are dropped from ceiling height. Installation of colored metal disks must follow completion of the finished surface on which the disks are to be fastened. The color code board must have the approximate dimensions of 3 foot width, 30 inches height, and 1/2 inch thickness. The board must be made of wood fiberboard and framed under glass or 1/16 inch transparent plastic cover. Unless otherwise directed, the color code symbols must be approximately 3/4 inch in diameter and the

related lettering in 1/2 inch high capital letters. The color code board must be mounted and located in the mechanical or equipment room. The color code system must be as indicated below:

Color	System	Item	Location

3.7 ESCUTCHEONS

Escutcheons must be provided at finished surfaces where bare or insulated piping, exposed to view, passes through floors, walls, or ceilings, except in boiler, utility, or equipment rooms. Escutcheons must be fastened securely to pipe or pipe covering and must be satin-finish, corrosion-resisting steel, polished chromium-plated zinc alloy, or polished chromium-plated copper alloy. Escutcheons must be either one-piece or split-pattern, held in place by internal spring tension or setscrew.

3.8 PAINTING

Painting of pipes, hangers, supports, and other iron work, either in concealed spaces or exposed spaces, is specified in Section 09 90 00 PAINTS AND COATINGS.

3.8.1 Painting of New Equipment

New equipment painting must be factory applied or shop applied, and must be as specified herein, and provided under each individual section.

3.8.1.1 Factory Painting Systems

Manufacturer's standard factory painting systems may be provided subject to certification that the factory painting system applied will withstand 125 hours in a salt-spray fog test, except that equipment located outdoors must withstand 500 hours in a salt-spray fog test. Salt-spray fog test must be in accordance with ASTM B117, and for that test the acceptance criteria must be as follows: immediately after completion of the test, the paint must show no signs of blistering, wrinkling, or cracking, and no loss of adhesion; and the specimen must show no signs of rust creepage beyond 0.125 inch on either side of the scratch mark.

The film thickness of the factory painting system applied on the equipment must not be less than the film thickness used on the test specimen. If manufacturer's standard factory painting system is being proposed for use on surfaces subject to temperatures above 120 degrees F, the factory painting system must be designed for the temperature service.

3.8.1.2 Shop Painting Systems for Metal Surfaces

Clean, pretreat, prime and paint metal surfaces; except aluminum surfaces need not be painted. Apply coatings to clean dry surfaces. Clean the surfaces to remove dust, dirt, rust, oil and grease by wire brushing and solvent degreasing prior to application of paint, except metal surfaces subject to temperatures in excess of 120 degrees F must be cleaned to bare metal.

Where more than one coat of paint is specified, apply the second coat after the preceding coat is thoroughly dry. Lightly sand damaged painting

and retouch before applying the succeeding coat. Color of finish coat must be aluminum or light gray.

- a. Temperatures Less Than 120 Degrees F: Immediately after cleaning, the metal surfaces subject to temperatures less than 120 degrees F must receive one coat of pretreatment primer applied to a minimum dry film thickness of 0.3 mil, one coat of primer applied to a minimum dry film thickness of one mil; and two coats of enamel applied to a minimum dry film thickness of one mil per coat.
- b. Temperatures Between 120 and 400 Degrees F: Metal surfaces subject to temperatures between 120 and 400 degrees F must receive two coats of 400 degrees F heat-resisting enamel applied to a total minimum thickness of 2 mils.
- c. Temperatures Greater Than 400 Degrees F: Metal surfaces subject to temperatures greater than 400 degrees F must receive two coats of 600 degrees F heat-resisting paint applied to a total minimum dry film thickness of 2 mils.

3.9 TESTS, FLUSHING AND DISINFECTION

Submit test reports in booklet form showing all field tests performed to adjust each component and all field tests performed to prove compliance with the specified performance criteria, completion and testing of the installed system. Each test report must indicate the final position of controls.

3.9.1 Plumbing System

The following tests must be performed on the plumbing system in accordance with IAPMO UPC, except that the drainage and vent system final test must include the smoke test. The Contractor has the option to perform a peppermint test in lieu of the smoke test. If a peppermint test is chosen, the Contractor must submit a testing procedure and reasons for choosing this option in lieu of the smoke test to the Contracting Officer for approval.

- a. Drainage and Vent Systems Test. The final test must include a smoke test.
- b. Building Sewers Tests.
- c. Water Supply Systems Tests.

3.9.1.1 Test of Backflow Prevention Assemblies

Certification of proper operation must be submitted and must be as accomplished in accordance with state regulations by an individual certified by the state to perform such tests. If no state requirement exists, the Contractor must have the manufacturer's representative test the device to ensure the unit is properly installed and performing as intended. The Contractor must provide written documentation of the tests performed and signed by the individual performing the tests. Backflow prevention assembly must be tested using gauges specifically designed for the testing of backflow prevention assemblies.

Backflow prevention assembly test gauges must be tested annually for accuracy in accordance with the requirements of State or local regulatory

agencies. If there is no State or local regulatory agency requirements, gauges must be tested annually for accuracy in accordance with the requirements of University of Southern California's Foundation of Cross Connection Control and Hydraulic Research or the American Water Works Association Manual of Cross Connection (Manual M-14), or any other approved testing laboratory having equivalent capabilities for both laboratory and field evaluation of backflow prevention assembly test gauges. Report form for each assembly must include, as a minimum, the following:

Data on Device	Data on Testing Firm
Type of Assembly	Name
Manufacturer	Address
Model Number	Certified Tester
Serial Number	Certified Tester No.
Size	Date of Test
Location	
Test Pressure Readings	Serial Number and Test Data of Gauges

If the unit fails to meet specified requirements, the unit must be repaired and retested.

3.9.1.2 Shower Pans

After installation of the pan and finished floor, the drain must be temporarily plugged below the weep holes. The floor area must be flooded with water to a minimum depth of 1 inch for a period of 24 hours. Any drop in the water level during test, except for evaporation, will be reason for rejection, repair, and retest.

3.9.1.3 Compressed Air Piping (Nonoil-Free)

Piping systems must be filled with oil-free dry air or gaseous nitrogen to 150 psig and hold this pressure for 2 hours with no drop in pressure.

3.9.2 Defective Work

If inspection or test shows defects, such defective work or material must be replaced or repaired as necessary and inspection and tests must be repeated. Repairs to piping must be made with new materials. Caulking of screwed joints or holes will not be acceptable.

3.9.3 System Flushing

3.9.3.1 During Flushing

Before operational tests or disinfection, potable water piping system must be flushed with hot potable water. Sufficient water must be used to produce a water velocity that is capable of entraining and removing debris in all portions of the piping system. This requires simultaneous

operation of all fixtures on a common branch or main in order to produce a flushing velocity of approximately 4 fps through all portions of the piping system. In the event that this is impossible due to size of system, the Contracting Officer (or the designated representative) must specify the number of fixtures to be operated during flushing. Contractor must provide adequate personnel to monitor the flushing operation and to ensure that drain lines are unobstructed in order to prevent flooding of the facility. Contractor must be responsible for any flood damage resulting from flushing of the system. Flushing must be continued until entrained dirt and other foreign materials have been removed and until discharge water shows no discoloration. All faucets and drinking water fountains, to include any device considered as an end point device by NSF/ANSI 61, Section 9, must be flushed a minimum of 0.25 gallons per 24 hour period, ten times over a 14 day period.

3.9.3.2 After Flushing

System must be drained at low points. Strainer screens must be removed, cleaned, and replaced. After flushing and cleaning, systems must be prepared for testing by immediately filling water piping with clean, fresh potable water. Any stoppage, discoloration, or other damage to the finish, furnishings, or parts of the building due to the Contractor's failure to properly clean the piping system must be repaired by the Contractor. When the system flushing is complete, the hot-water system must be adjusted for uniform circulation. Flushing devices and automatic control systems must be adjusted for proper operation according to manufacturer's instructions. Flow rates on fixtures must not exceed those stated in PART 2 of this Section. Unless more stringent local requirements exist, lead levels must not exceed limits established by 40 CFR 141.80 (c)(1). The water supply to the building must be tested separately to ensure that any lead contamination found during potable water system testing is due to work being performed inside the building.

3.9.4 Operational Test

Upon completion of flushing and prior to disinfection procedures, the Contractor must subject the plumbing system to operating tests to demonstrate satisfactory installation, connections, adjustments, and functional and operational efficiency. Such operating tests must cover a period of not less than 8 hours for each system and must include the following information in a report with conclusion as to the adequacy of the system:

- a. Time, date, and duration of test.
- b. Water pressures at the most remote and the highest fixtures.
- c. Operation of each fixture and fixture trim.
- d. Operation of each valve, hydrant, and faucet.
- e. Pump suction and discharge pressures.
- f. Temperature of each domestic hot-water supply.
- g. Operation of each floor and roof drain by flooding with water.
- h. Operation of each vacuum breaker and backflow preventer.

- j. Compressed air readings at each compressor and at each outlet. Each indicating instrument must be read at 1/2 hour intervals. The report of the test must be submitted in quadruplicate. The Contractor must furnish instruments, equipment, and personnel required for the tests; the Government will furnish the necessary water and electricity.

3.9.5 Disinfection

After all system components are provided and operational tests are complete, the entire domestic hot- and cold-water distribution system must be disinfected. Before introducing disinfecting chlorination material, entire system must be flushed with potable water until any entrained dirt and other foreign materials have been removed.

Water chlorination procedure must be in accordance with AWWA C651 and AWWA C652 as modified and supplemented by this specification. The chlorinating material must be hypochlorites or liquid chlorine. The chlorinating material must be fed into the water piping system at a constant rate at a concentration of at least 50 parts per million (ppm). Feed a properly adjusted hypochlorite solution injected into the system with a hypochlorinator, or inject liquid chlorine into the system through a solution-feed chlorinator and booster pump until the entire system is completely filled.

3.9.5.1 Water Chlorination Monitoring

Test the chlorine residual level in the water at 6 hour intervals for a continuous period of 24 hours. If at the end of a 6 hour interval, the chlorine residual has dropped to less than 25 ppm, flush the piping including tanks with potable water, and repeat the above chlorination procedures. During the chlorination period, each valve and faucet must be opened and closed several times. After the second 24 hour period, verify that no less than 25 ppm chlorine residual remains in the treated system. The 24 hour chlorination procedure must be repeated until no less than 25 ppm chlorine residual remains in the treated system.

3.9.5.2 Water Chlorination Flushing

Upon the specified verification, the system including tanks must then be flushed with potable water until the residual chlorine level is reduced to less than one part per million. During the flushing period, each valve and faucet must be opened and closed several times.

3.9.5.3 Sample Testing

Take additional samples of water in disinfected containers, for bacterial examination, at locations specified by the Contracting Officer. Test these samples for total coliform organisms (coliform bacteria, fecal coliform, streptococcal, and other bacteria) in accordance with EPA SM 9223. The testing method used must be EPA approved for drinking water systems and must comply with applicable local and state requirements.

3.9.5.4 Disinfection Acceptance

Disinfection must be repeated until bacterial tests indicate the absence of coliform organisms (zero mean coliform density per 100 milliliters) in the samples for at least 2 full days. The system will not be accepted until satisfactory bacteriological results have been obtained.

3.10 POSTED INSTRUCTIONS

Framed instructions under glass or in laminated plastic, including wiring and control diagrams showing the complete layout of the entire system, must be posted where directed. Condensed operating instructions explaining preventive maintenance procedures, methods of checking the system for normal safe operation, and procedures for safely starting and stopping the system must be prepared in typed form, framed as specified above for the wiring and control diagrams and posted beside the diagrams. The framed instructions must be posted before acceptance testing of the systems.

3.11 PERFORMANCE OF WATER HEATING EQUIPMENT

Standard rating condition terms are as follows:

DP = Draw pattern

EF = Energy factor, minimum overall efficiency.

ET = Minimum thermal efficiency with 70 degrees F delta T.

SL = Standby loss is maximum (Btu/h) based on a 70 degrees F temperature difference between stored water and ambient requirements.

UEF = Uniform energy factor

V = Rated volume in gallons

Q = Nameplate input rate in kW (Btu/h)

3.11.1 Storage Water Heaters

3.11.1.1 Electric

- a. Storage capacity more than or equal to 20 gallons and less than or equal to 55 gallons with a draw pattern (DP) of: very small must have a uniform energy factor (UEF) of $0.8808 - (0.0008 \times V)$, low must have a uniform energy factor (UEF) of $0.9254 - (0.0003 \times V)$, medium must have a uniform energy factor (UEF) of $0.9307 - (0.0002 \times V)$, high must have a uniform energy factor (UEF) of $0.9349 - (0.0001 \times V)$ per 10 CFR 430.
- b. Storage capacity more than 55 gallons and less than or equal to 120 gallons with a draw pattern (DP) of: very small must have a uniform energy factor (UEF) of $1.9236 - (0.0011 \times V)$, low must have a uniform energy factor (UEF) of $2.0440 - (0.0011 \times V)$, medium must have a uniform energy factor (UEF) of $2.1171 - (0.0011 \times V)$, high must have a uniform energy factor (UEF) of $2.418 - (0.0011 \times V)$ per 10 CFR 430.

3.11.1.2 Gas

- a. Storage capacity more than or equal to 20 gallons and less than or equal to 55 gallons with a draw pattern (DP) of: very small must have a uniform energy factor (UEF) of $0.3456 - (0.0020 \times V)$, low must have a uniform energy factor (UEF) of $0.5982 - (0.0019 \times V)$, medium must have a uniform energy factor (UEF) of $0.6483 - (0.0017 \times V)$, high must have a uniform energy factor (UEF) of $0.6920 - (0.0013 \times V)$ per 10 CFR 430.

- b. Storage capacity more than 55 gallons and less than or equal to 100 gallons with a draw pattern (DP) of: very small must have a uniform energy factor (UEF) of $0.6470 - (0.0006 \times V)$, low must have a uniform energy factor (UEF) of $0.7689 - (0.0005 \times V)$, medium must have a uniform energy factor (UEF) of $0.7897 - (0.0004 \times V)$, high must have a uniform energy factor (UEF) of $0.8702 - (0.0003 \times V)$ per 10 CFR 430.
- c. Storage capacity less than or equal to 120 gallons with input rating more than 75,000 Btu/h and less than 105,000 Btu/h with a draw pattern (DP) of: very small must have a uniform energy factor (UEF) of $0.2674 - (0.0009 \times V)$, low must have a uniform energy factor (UEF) of $0.5362 - (0.0012 \times V)$, medium must have a uniform energy factor (UEF) of $0.6002 - (0.0011 \times V)$, high must have a uniform energy factor (UEF) of $0.6597 - (0.0009 \times V)$ per 10 CFR 430.

3.11.1.3 Oil

- a. Storage capacity less than or equal to 50 gallons with a draw pattern (DP) of: very small must have a uniform energy factor (UEF) of $0.2509 - (0.0012 \times V)$, low must have a uniform energy factor (UEF) of $0.5330 - (0.0016 \times V)$, medium must have a uniform energy factor (UEF) of $0.6078 - (0.0016 \times V)$, high must have a uniform energy factor (UEF) of $0.6815 - (0.0014 \times V)$ per 10 CFR 430.
- b. Storage capacity less than or equal to 120 gallons with input rating more than 105,000 Btu/h and less than or equal to 140,000 Btu/h with a draw pattern (DP) of: very small must have a uniform energy factor (UEF) of $0.2932 - (0.0015 \times V)$, low must have a uniform energy factor (UEF) of $0.5596 - (0.0018 \times V)$, medium must have a uniform energy factor (UEF) of $0.6194 - (0.0016 \times V)$, high must have a uniform energy factor (UEF) of $0.6740 - (0.0013 \times V)$ per 10 CFR 430.

3.11.2 Unfired Hot Water Storage

All volumes and inputs: must meet or exceed R-12.5.

3.11.3 Instantaneous Water Heater

3.11.3.1 Electric

- a. Storage capacity less than 2 gallons with a draw pattern (DP) of: very small must have a uniform energy factor (UEF) of 0.91, low must have a uniform energy factor (UEF) of 0.91, medium must have a uniform energy factor (UEF) of 0.91, high must have a uniform energy factor (UEF) of 0.92 per 10 CFR 430.

3.11.3.2 Gas

- a. Storage capacity less than 2 gallons input rating greater than 50,000 Btu/h with a draw pattern (DP) of: very small must have a uniform energy factor (UEF) of 0.80, low must have a uniform energy factor (UEF) of 0.81, medium must have a uniform energy factor (UEF) of 0.81, high must have a uniform energy factor (UEF) of 0.81 per 10 CFR 430.
- b. Rating of 4,000 Btu/h/gal and storage capacity less than 10 gallons with an input of 200,000 Btu/h must have a minimum thermal efficiency (ET) of 80 percent per ANSI Z21.10.3/CSA 4.3.

- c. Rating of 4,000 BTU/h/gal and storage capacity more than 10 gallons with an input more than 200,000 Btu/h must have a minimum thermal efficiency (ET) of 80 percent and the maximum SL must be $Q/800+110x(V^{1/2})$ per ANSI Z21.10.3/CSA 4.3.

3.11.3.3 Oil

- a. Rating of 4,000 Btu/h/gal and storage capacity less than 2 gallons with an input more than 50,000 Btu/h and less than 210,000 Btu/h must have an energy factor (EF) of 0.59 - (0.0005 x V per 10 CFR 430.
- b. Rating of 4,000 Btu/h/gal and storage capacity less than 10 gallons with an input more than 10 gallons with an input more than 210,000 Btu/h must have a minimum thermal efficiency (ET) of 80 percent per ANSI Z21.10.3/CSA 4.3.
- c. Rating of 4,000 Btu/h/gal and storage capacity more than 10 gallons with an input of more than 210,000 Btu/h must have a minimum thermal efficiency (ET) of 78 percent and the maximum SL must be $Q/800+110x(V^{1/2})$ per ANSI Z21.10.3/CSA 4.3.

3.11.4 Pool Heaters

- a. Gas/oil fuel, capacities and inputs: ET must be 78 percent per ASHRAE 146.
- b. Heat Pump, All capacities and inputs must meet a COP of 4.0 per ASHRAE 146

3.12 TABLES

TABLE I								
PIPE AND FITTING MATERIALS FOR DRAINAGE, WASTE, VENT AND CONDENSATE DRAIN PIPING SYSTEMS								
Item #	Pipe and Fitting Materials	SERVICE <u>A</u>	SERVICE <u>B</u>	SERVICE <u>C</u>	SERVICE <u>D</u>	SERVICE <u>E</u>	SERVICE <u>F</u>	SERVICE <u>G</u>
1	Cast iron soil pipe and fittings, hub and spigot, ASTM A74 with compression gaskets. Pipe and fittings must be marked with the CISPI trademark.	X	X	X	X	X		

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2	Cast iron soil pipe and fittings hubless, CISPI 301 and ASTM A888. Pipe and fittings must be marked with the CISPI trademark.		X		X	X		
3	Cast iron drainage fittings, threaded, ASME B16.12 for use with Item 10	X		X	X			
4	Cast iron screwed fittings (threaded) ASME B16.4 for use with Item 10				X	X		
5	Grooved pipe couplings, ferrous and non-ferrous pipe ASTM A536 And ASTM A47/A47M	X	X		X	X		
6	Ductile iron grooved joint fittings for ferrous pipe ASTM A536 and ASTM A47/A47M for use with Item 5	X	X		X	X		

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7	Bronze sand casting grooved joint pressure fittings for non-ferrous pipe ASTM B584, for use with Item 5	X	X		X	X		
8	Wrought copper grooved joint pressure fittings for non-ferrous pipe ASTM B75/B75M C12200, ASTM B152/B152M, C11000, ASME B16.22 ASME B16.22 for use with Item 5	X	X					
9	Malleable-iron threaded fittings, galvanized ASME B16.3 for use with Item 10				X	X		
10	Steel pipe, seamless galvanized, ASTM A53/A53M, Type S, Grade B				X	X		
11	Seamless red brass pipe, ASTM B43				X	X		X

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Item #	Pipe and Fitting Materials	SERVICE <u>A</u>	SERVICE <u>B</u>	SERVICE <u>C</u>	SERVICE <u>D</u>	SERVICE <u>E</u>	SERVICE <u>F</u>	SERVICE <u>G</u>
12	Bronzed flanged fittings, ASME B16.24 for use with Items 11 and 14				X	X		X
13	Cast copper alloy solder joint pressure fittings, ASME B16.18 for use with Item 14				X	X		X
14	Seamless copper pipe, ASTM B42						X	X
15	Cast bronze threaded fittings, ASME B16.15				X	X		
16	Copper drainage tube, (DWV), ASTM B306	X*	X	X*	X	X		X
17	Wrought copper and wrought alloy solder-joint drainage fittings. ASME B16.29	X	X	X	X	X		X
18	Cast copper alloy solder joint drainage fittings, DWV, ASME B16.23	X	X	X	X	X		X

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19	Acrylonitrile-Butadiene-Styrene (ABS) plastic drain, waste, and vent pipe and fittings ASTM D2661, ASTM F628	X	X	X	X	X	X	
20	Polyvinyl Chloride plastic drain, waste and vent pipe and fittings, ASTM D2665, ASTM F891, (Sch 40) ASTM F1760	X	X	X	X	X	X	X
21	Process glass pipe and fittings, ASTM C1053						X	
22	High-silicon content cast iron pipe and fittings (hub and spigot, and mechanical joint), ASTM A518/A518M		X			X	X	
23	Polypropylene (PP) waste pipe and fittings, ASTM D4101						X	
24	Filament-wound reinforced thermosetting resin (RTRP) pipe, ASTM D2996						X	

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25	Cast Iron pipe and fittings, CEN EN 877 piping	X	X	X	X	X	X	
SERVICE: A - Underground Building Soil, Waste and Storm Drain B - Aboveground Soil, Waste, Drain In Buildings C - Underground Vent D - Aboveground Vent E - Interior Rainwater Conductors Aboveground F - Corrosive Waste And Vent Above And Belowground G - Condensate Drain Aboveground * - Hard Temper								

TABLE III					
STANDARD RATING CONDITIONS AND MINIMUM PERFORMANCE RATINGS FOR WATER HEATING EQUIPMENT					
FUEL	STORAGE CAPACITY OR RATING CONDITION	INPUT RATING	TEST PROCEDURE	REQUIRED PERFORMANCE	
A. STORAGE WATER HEATERS					
Elect.	>20 gal and ≤55 gal		10 CFR 430	DP	UEF
				Very Small	0.8808 - (0.0008 x V)
				Low	0.9254 - (0.0003 x V)
				Medium	0.9307 - (0.0002 x V)
				High	0.9349 - (0.0001 x V)
Elect.	>55 gal and ≤120 gal		10 CFR 430	DP	UEF
				Very Small	1.9236 - (0.0011 x V)
				Low	2.0440 - (0.0011 x V)
				Medium	2.1171 - (0.0011 x V)
				High	2.2418 - (0.0011 x V)
Elect. Heat Pump		<24 Amps and ≤250 Volts	10 CFR 430	Rating Condition	UEF
				Integrated heat pump water heater (HPWH)	UEF ≥3.3 and First Hour Rating ≥45 gal/h
				Integrated HPWH, >120 V/15 Amp Circuit or Split-System HPWH	UEF ≥2.2 and First Hour Rating ≥45 gal/h
Elect. Heat Pump		>12 kW	10 CFR 430	HPWH COP ≥3.0	

TABLE III					
STANDARD RATING CONDITIONS AND MINIMUM PERFORMANCE RATINGS FOR WATER HEATING EQUIPMENT					
<u>FUEL</u>	<u>STORAGE CAPACITY OR RATING CONDITION</u>	<u>INPUT RATING</u>	<u>TEST PROCEDURE</u>	<u>REQUIRED PERFORMANCE</u>	
Gas	>20 gal and <55 gal		10 CFR 430	DP	UEF
				Very Small	0.3456 - (0.0020 x V)
				Low	0.5982 - (0.0019 x V)
				Medium	0.6483 - (0.0017 x V)
				High	0.6920 - (0.0013 x V)
Gas	>55 gal and <100 gal		10 CFR 430	DP	UEF
				Very Small	0.6470 - (0.0006 x V)
				Low	0.7689 - (0.0005 x V)
				Medium	0.7897 - (0.0004 x V)
				High	0.8072 - (0.0003 x V)
Gas	<120 gal	75,000 Btu/h	10 CFR 430	DP	UEF
				Very Small	0.2674 - (0.0009 x V)
				Low	0.5362 - (0.0012 x V)
				Medium	0.6002 - (0.0011 x V)
				High	0.6597 - (0.0009 x V)
Oil	<50 gal		10 CFR 430	DP	UEF
				Very Small	0.2509 - (0.0012 x V)
				Low	0.5330 - (0.0016 x V)
				Medium	0.6078 - (0.0016 x V)
				High	0.6815 - (0.0014 x V)

TABLE III					
STANDARD RATING CONDITIONS AND MINIMUM PERFORMANCE RATINGS FOR WATER HEATING EQUIPMENT					
FUEL	STORAGE CAPACITY OR RATING CONDITION	INPUT RATING	TEST PROCEDURE	REQUIRED PERFORMANCE	
				DP	UEF
Oil	<120 gal	>105,000 Btu/h and ≤ 140,000 Btu/h	10 CFR 430	DP	UEF
				Very Small	0.2932 - (0.0015 x V)
				Low	0.5596 - (0.0018 x V)
				Medium	0.6194 - (0.0016 x V)
				High	0.6740 - (0.0013 x V)
B. Unfired Hot Water Storage, R-12.5 min.					
C. Instantaneous Water Heater					
Elect.	<2 gal		10 CFR 430	DP	UEF
				Very Small	0.91
				Low	0.91
				Medium	0.91
				High	0.92
Gas	<2 gal and >50,000 Btu/h		10 CFR 430	DP	UEF
				Very Small	0.80
				Low	0.81
				Medium	0.81
				High	0.81
Gas	4,000 (btu/h)/gal and 10 gal max.	200,000 Btu/h min.	ANSI Z21.10.3/C	ET = 80 percent	
Gas	4,000 (btu/h)/gal and 10 gal max.	200,000 Btu/h min.	ANSI Z21.10.3/C	ET = 80 percent SL = (Q/800+110x(V ^{1/2}))	
Oil	4,000 (btu/h)/gal and 2 gal max.	50,000 Btu/h min. 210,000 Btu/h max.	10 CFR 430	ET = 80 percent and EF = 0.59-0.0005V	

TABLE III				
STANDARD RATING CONDITIONS AND MINIMUM PERFORMANCE RATINGS FOR WATER HEATING EQUIPMENT				
<u>FUEL</u>	<u>STORAGE CAPACITY OR RATING CONDITION</u>	<u>INPUT RATING</u>	<u>TEST PROCEDURE</u>	<u>REQUIRED PERFORMANCE</u>
Oil	4,000 (btu/h)/gal and 10 gal max.	210,000 Btu/h min.	ANSI Z21.10.3/C	ET = 80 percent
Oil	4,000 (btu/h)/gal and 10 gal max.	210,000 Btu/h min.	ANSI Z21.10.3/C	ET = 78 percent SL = (Q/800+110x(V ^{1/2})) max.
D. Pool Heater				
Gas or Oil	All	All	ASHRAE 146	ET = 82 percent
Heat Pump All	All	All	ANSI/AHRI 1160	COP = 4.0
TERMS: DP = Draw Pattern EF = Energy factor, minimum overall efficiency. ET = Minimum thermal efficiency with 70 degrees F delta T. SL = Standby loss is maximum Btu/h based on a 70 degree F temperature difference between stored water and ambient requirements. UEF = Uniform energy factor V = Rated storage volume in gallons Q = Nameplate input rate in Btu/h				

-- End of Section --

SECTION 22 15 19.19 20

NONLUBRICATED ROTARY SCREW AIR COMPRESSORS (100 HP AND LARGER)
05/11

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN BEARING MANUFACTURERS ASSOCIATION (ABMA)

ABMA 9 (2015) Load Ratings and Fatigue Life for Ball Bearings

ABMA 11 (2014) Load Ratings and Fatigue Life for Roller Bearings

AMERICAN GEAR MANUFACTURERS ASSOCIATION (AGMA)

AGMA 2011 (2014B) Cylindrical Wormgearing Tolerance and Inspection Methods

ANSI/AGMA 2009 (2001B; R 2008) Bevel Gear Classification, Tolerances, and Inspection Methods

AMERICAN PETROLEUM INSTITUTE (API)

API Std 619 (2010) Rotary-Type Positive Displacement Compressors for Petroleum, Petrochemical, and Natural Gas Industries

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B1.20.1 (2013; R 2018) Pipe Threads, General Purpose (Inch)

ASME B16.1 (2020) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250

ASME B16.5 (2020) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard

ASME B40.100 (2022) Pressure Gauges and Gauge Attachments

ASME BPVC SEC VIII D1 (2019) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1

ASME PTC 9 (1970; R 1997) Displacement Compressors, Vacuum Pumps and Blowers (for historical reference only)

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M	(2019) Standard Specification for Carbon Structural Steel
ASTM B111/B111M	(2018) Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock
ASTM B171/B171M	(2012) Standard Specification for Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers and Heat Exchangers
ASTM B209	(2014) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM C553	(2013; R 2019) Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
ASTM E84	(2023) Standard Test Method for Surface Burning Characteristics of Building Materials

COMPRESSED GAS ASSOCIATION (CGA)

CGA G-7.1	(2011) Commodity Specification for Air; 5th Edition
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INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 112	(2017) Standard Test Procedure for Polyphase Induction Motors and Generators
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INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 2151	(2004) Acoustics - Noise Test Code for Compressors and Vacuum Pumps - Engineering Method (Grade 2)
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NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 2	(2000; R 2020) Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 V
NEMA ICS 6	(1993; R 2016) Industrial Control and Systems: Enclosures
NEMA MG 1	(2021) Motors and Generators

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-A-3316	(1987; Rev C; Am 2 1990) Adhesives, Fire-Resistant, Thermal Insulation
MIL-T-19646	(1990; Rev A; Notice 1 2021) Thermometer, Gas Actuated, Remote Reading

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

29 CFR 1910.219

Mechanical Power Transmission Apparatus

1.2 GENERAL REQUIREMENTS

Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND METHODS, applies to this section except as specified herein.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Air Compressor System

SD-03 Product Data

Air Compressor

Inlet Air Filters

Line Silencer

Air Flow Rate and Pressure Recorder

Carbon Monoxide Monitor

Filter Housing

Submit manufacturer's catalog data for compressor and auxiliary equipment in the format provided in API Std 619, Appendix A. For air compressors, include intercoolers, oil cooler, lubrication system, and control valves. Submit air compressor, intercooler, aftercooler, and bypass cooler performance curves at specified summer and winter design conditions. For electric motors include overall physical features dimensions, ratings, service requirements, efficiency, and weight of equipment.

SD-06 Test Reports

Air compressor performance tests

Sound Level Tests

Obtain approval prior to shipping compressor.

Government must have the option to observe test procedures and vendor will provide two (2) copies of test results and two (2) copies of maintenance manuals.

Air Compressor Performance Tests

Instrumentation Test

Sound Level and Run-in Tests

Air Compressor System Test

The test supervisor must certify performance by test to be in compliance with specifications.

SD-07 Certificates

Work Plan

Factory Test Procedures

Factory Testing Certification

Qualifications of Field Supervisors

Field Test Procedures

Training Material

Air Compressor System

Air Compressor System Installation

SD-10 Operation and Maintenance Data

Air Compressor System, Data Package 3

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. Data must contain information required for maintenance and repair and must contain no evidence that proprietary maintenance arrangements with the manufacturer will be necessary. Compressors which will require proprietary maintenance arrangement with the manufacturer require Government review and approval. The compressors may be disapproved if circumstances do not justify approval of compressors with limited availability of maintenance.

SD-11 Closeout Submittals

Posted Operating Instructions for Air Compressor

Submit text.

1.4 QUALITY ASSURANCE

1.4.1 Work Plan

Submit a written schedule of dates of installation, start-up, checkout, and test of equipment.

1.4.2 Factory Testing Certification

Submit a statement that the air compressor factory is equipped to perform all required factory tests. Submit in accordance with paragraph entitled "Manufacturer's Certifications."

1.4.3 Qualifications of Field Supervisors

Submit the name and certified written resume of the engineer or technician, listing education, factory training and installation, start-up, and testing supervision experience for at least two projects involving compressors similar to those in this contract.

1.4.4 Training Material

Submit a detailed training program syllabus for training government personnel, including instructional materials at least three weeks prior to start of tests.

1.4.5 System Installation

Submit certification of performance conforming to ASME PTC 9 and ASME BPVC SEC VIII D1. Submit certification of proper installation in accordance with paragraph entitled "Supervision."

1.5 SAFETY

Construct all components of the unit in accordance with the requirements of OSHA 29 CFR 1910.219. Requirements include shaft coupling guards as specified in Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND METHODS insulation and jacketing with manufacturer standard covering or aluminum sheet of all surfaces at 125 degrees F and higher within a height of 7 feet from floor level, and use of electrical safety devices. Thermal insulation, furnished by equipment manufacturer, must conform to ASTM C553, Type I (flexible resilient), Class B-5 (up to 400 degrees F), 2 pcf nominal. Cement insulation to surface with MIL-A-3316, Class 2, adhesive and fasten with 16-gage wire bands at maximum 16 inches on center spacing. Cover insulation with ASTM B209 sheet aluminum jacket. However, insulation is not required for hot piping inside sound enclosure.

1.6 EQUIPMENT ARRANGEMENT

Arrangement selected must maintain 3 foot clearance for access passage and 4 foot clearance for personnel to operate equipment. There are substantial physical and connection point differences among the several air compressors which comply with this specification. The Contractor must be responsible for selecting equipment and submitting arrangement drawings covering required changes for approval by the Contracting Officer. Changes from the equipment arrangement shown on the contract drawings must be performed by the Contractor at no additional cost to the Government.

1.6.1 Air Compressor System

Include wiring diagrams of the air compressor with all accessories. The minimum acceptable scale is 1/4 inch to one foot .

1.7 ELECTRICAL REQUIREMENTS

Comply with the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM .

1.8 SUPERVISION

The Contractor must obtain the services of a qualified engineer or

technician from the compressor manufacturer to supervise installation, start-up, and testing of the compressor. After satisfactory installation of the equipment, the engineer or technician must provide a signed certification that the equipment is installed in accordance with the manufacturer's recommendations.

1.9 DEFINITIONS

Conform to API Std 619 and the following:

Compressor power is shaft power at shaft coupling, including all losses and connected appurtenances.

1.10 INSULATION

Thermal and acoustical insulation must have flame spread rating not higher than 75, and smoke developed rating not higher than 150 when tested in accordance with ASTM E84.

1.11 POSTED OPERATING INSTRUCTIONS

Provide for air compressor. Include start-up and shutdown sequence instructions.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

Materials and equipment complete with accessories must be selected by the Contractor for performance compatibility.

2.2 AIR COMPRESSOR

The air compressors must be packaged, positive displacement rotary screw compressors capable of delivering oil-free air. No lubricant must be used within the compression chamber. Include air compressor, electric motor driver, coolers, lubrication system, and regulation and control systems mounted on a common base frame, and completely enclosed for noise control.

2.2.1 Manufacturer's Certifications

The manufacturer must certify that the air compressors proposed are of the same design, construction, size, and of equal or not more than 10 percent smaller in capacity as compressors which have been in satisfactory continuous service for at least 2 years at not less than two locations. Furnish the name of the owner, the address of the installation, and the name of a person at the installation who can be contacted for verification. The manufacturer must also certify that the factory is equipped to perform all required factory tests.

2.2.2 Guaranteed Performance

- a. Net compressed air output (All seal losses must be considered internal and not included in the net output) (plus or minus 2 percent): SCFM
- b. Output pressure immediately downstream of aftercooler (minus zero plus 4 percent): 125 psig
- c. Output air maximum temperature downstream of aftercooler: 100 degrees

F

f. Inlet air filtration efficiency: 99.9 percent of 0.5 micron size

n. Maximum sound levels one meter horizontal from compressor and 1.5 meters above floor as measured per ISO 2151 Test Code for the Measurement of Sound from Pneumatic Equipment: 84 dBA, 90dB for any octave band.

2.2.3 Additional Performance Requirements

2.2.3.1 Air Quality

Air at compressor intake will be considered breathing air quality conforming to CGA G-7.1, Type I, Grade D or better. Air compressors must introduce no material, gases, or particles, or chemically alter any materials that will adversely affect or reduce the quality of the air passing through the unit.

2.2.3.2 Ambient and Inlet Conditions Operating Ranges

Allowing for rational engineering performance adjustments due to variations in ambient and inlet conditions, the compressor must be designed, equipped, and furnished to be fully operational without abnormal wear throughout the entire range between and including the limits of the winter and summer design conditions specified.

a. Summer Design Conditions:

Inlet Air: 99.1 degrees F dry bulb and 74.2 degrees F wet bulb temperatures, F, Ambient Compressor Room Temperature: 100 degrees F,

b. Winter Design Conditions:

Inlet Air: 33.0 degrees F dry bulb and degrees F , F, Ambient Compressor Room Temperature: 55.0 degrees F, .

2.2.3.3 Critical Speeds

Actual critical speeds must not encroach upon operating speed ranges at specified loads ranges. Rotors must be of a stiff shaft construction with

the first actual rotor bending critical speed at least 120 percent of the maximum operating speed.

2.2.3.4 Vibration and Balance

Major parts of rotating elements, such as rotors, gears, and similar items must be individually dynamically balanced. During the factory and site tests of the assembled machine at operating speed, the double amplitude of vibration in any plane measured on the shaft adjacent and relative to a radial bearing must not exceed the limits of API Std 619, paragraph 2.7.2.5. For shafts which are not accessible, the manufacturer must submit a testing procedure to the Contracting Officer for approval.

2.2.4 Electrical Service Conditions

2.2.4.1 Air Compressor Drive Motor

480 volts, 3 phase, 3 wire, 60 hertz electrical service.

2.2.4.2 Accessory electrical Service

See Table I.

<u>TABLE I - COMPRESSOR ACCESSORY ELECTRICAL SERVICE SCHEDULE</u>			
<u>Item</u>	<u>Voltage</u>	<u>Phase</u>	<u>Frequency</u>
Control Power and Motors under 1/2 hp	120	1	60 Hz
Accessory Power	460	3	60 Hz

2.2.5 Compressor Controls

Provide a complete load regulation and control system with the compressor. Provide additional electrical, electro-pneumatic, or solid state electronic controls for other specified control and monitor functions. All electrical controls must conform to NEMA ICS 2 as selected by the compressor manufacturer. Control system enclosure must conform to NEMA ICS 6. Controls must be suitable for individual operation of the compressor or parallel operation with one or more other compressors.

2.2.5.1 Compressor Start-Up

The compressor must start unloaded. The manual starting circuit for the compressor must have interlocks to prevent the compressor drive motor from starting until pre-lubrication pump (if provided), oil pressure, and cooling water pump water flow have been established to the required values for safe operation as determined by the compressor manufacturer.

2.2.5.2 Load Regulation

The compressor must operate continuously at constant speed after being started. Provide means to load and unload the compressor automatically at preset minimum and maximum pressure settings. Minimum pressure must be 100 psig, and maximum pressure must be 125 psig. Unloading must be accomplished by a combination of closing the inlet valve and bypassing or venting the outlet of the compressor; however, input power at fully

unloaded operation must not exceed 20 percent of full load input. Bypassed air must be cooled by the bypass cooler and if returned to the inlet of the first stage through an internal loop and must be limited to the minimum flow required to maintain compressor cooling. Air vented to the atmosphere when unloading need not be cooled.

2.2.5.3 Monitor and Safety Controls

Provide supplementary electric, electro-pneumatic, or solid state electronic controls to provide alarm and shutdown requirements, plus interlocks with accessories. Requirements are as follows:

- a. Shutdown requirements must cause the controlled compressor to shut down, energize alarms, and light labeled red lights.
- b. Alarm only requirements must not cause the controlled compressor to shut down, but must sound the same alarms and light labeled amber lights.
- c. Light only requirements must not cause the controlled compressor to shut down, but must light labeled amber lights.
- d. The individual monitor and safety controls must be as shown on Table 2.

<u>TABLE 2 - MONITOR AND SAFETY CONTROL SCHEDULE</u>			
<u>Item</u>	<u>Light and Shutdown</u>	<u>Indicating Alarm</u>	<u>Light Only</u>
1. High Discharge Air Temperature 275 degrees F	Yes	Yes	-
2. High Intercooler Discharge Water Temperature, Each Intercooler	No	Yes	-
3. High Aftercooler Discharge Water Temperature	No	Yes	-
4. High Cooling Water Supply Temperature	No	Yes	-
5. High Lube Oil Temperature	Yes	Yes	-
6. Low Lube Oil Pressure	Yes	Yes	-
7. Low Cooling Water Flow	No	Yes	-
8. Low Oil Reservoir Level	No	Yes	-
9. High Condensate Level Intercooler (wired to one light)	No	No	Yes
10. High Bleed-Off Air Pressure	Yes	Yes	-

11. High Motor Stator Temperature	Yes	Yes	-
12. High Condensate Level Aftercooler	No	No	Yes
13. High Inlet Pressure Drop Across Inlet Air Filters (combined, 3 stage)	No	Yes	-
14. High CO Level	Yes	Yes	-

2.2.5.4 Monitoring Instruments

Provide the following monitoring instruments in addition to the monitor and safety controls. Pressure gages must conform to ASME B40.100, 4 1/2 inch diameter, red marking pointer, single bourdon tube, brass case, black enamel finish. Provide pressure gages with a pressure snubber and a stainless steel barstock needle isolation valve. Thermometers must be extended stainless steel sheathed bimetallic stem, 3 1/2 inch dial, and separable 4 inch stainless steel wells. Temperature measurements at inaccessible locations must be made with remote reading thermometers conforming to MIL-T-19646, Class C separable well of Type 304 stainless steel. Select pressure and temperature gage ranges to give a normal operating reading near the midpoint of the scale range.

- a. Oil cooler outlet temperature gages for oil.
- b. Oil cooler inlet temperature gages for water.
- c. Lubrication oil bearing supply pressure gage.
- d. Compressor seal air pressure gage (if applicable).
- e. Inlet air filter differential pressure gage with 8, zero, 8 inch water gage. Provide selector valve, tubing, and tap to measure static gage pressure downstream of each filter stage.
- f. Total running time readout.
- g. Cooling water supply to compressor pressure gage.
- h. Cooling water return from compressor pressure gage.
- i. Interstage air pressure gages for each interstage.
- j. Compressed air pressure downstream of aftercooler pressure gage.
- k. Compressed air temperature downstream of aftercooler temperature gage.
- l. Compressed air temperature at discharge of each stage of compression before cooling temperature gages.
- m. Interstage air temperature after intercooler of each stage temperature gages.
- n. Compressor inlet air temperature gage.
- o. Cooling water to compressor temperature gage.

- p. Cooling water outlet temperature at each outlet of each intercooler, aftercooler, and bypass air cooler temperature gages.

2.2.6 Compressor Design Features

The compressor must be a multistage, oil-free rotary screw compressor, with a minimum of two compressor stages, flanged to an integral speed increaser. Each stage must be driven from a common bull gear to ensure optimum speed and efficiency. An intercooler must be provided between stages and aftercooler must be provided after the final stage of compression. Silencers, lubricating system, cooling system, control system, and driver must be mounted as part of the package. Provide a common base frame for the compressor system and driver. Provide a sound enclosure over the compressor and driver. Equipment must be designed for economical and rapid maintenance. Casing components, bearing housings, and other major parts must be shouldered, dowelled, or designed with other provisions to facilitate accurate alignment or reassembly. Shaft seals and bearings must be accessible for inspection or replacement with a minimum of disassembly; however, compressors with compression elements (air end) provided as a factory-assembled not repairable in the field may be approved by the Contracting Officer if determined to be in the interest of the Government.

2.2.6.1 Casings

Casings must be cast iron, ductile iron, cast steel, or fabricated steel. Casing stresses must be within the limits allowed by ASME BPVC SEC VIII D1. Casings, supports, and baseplates must be designed and fabricated to preclude excessive and injurious distortion from temperatures, pressures, and forces encountered in service conditions. Provide jackscrews, lifting lugs, eyebolts, guide dowels, and casing alignment dowels to facilitate disassembly and reassembly. When using jackscrews for parting contacting faces, relieve one of the faces by counterboring or recessing to prevent marring the face, which result in leaking or improper fit. Provide lifting lugs or eyebolts for removable portions of the casings. Flanged casing connections for external piping must conform to ASME B16.1 or ASME B16.5. Threaded connections for external piping must conform to ASME B1.20.1. Air compression portion of the casing must be one-piece and must be provided with integral coolant passages and a large inlet port. Gear cases must be enclosed, accessible, force lubricated, and designed with seals and slingers to keep oil out of air system.

2.2.6.2 Shafts

Shafts must be of forged or rolled alloy steel and must have a machined finish throughout their entire length. All rotating components must be positively secured to shafts by approved mechanical means or interference shrink fits.

2.2.6.3 Rotors

Rotors must be steel, and of one-piece construction, with an asymmetric profile to minimize leakage losses, and ensure high efficiency. Rotors must be treated for corrosion resistance. If rotors are welded to the shaft, the assembly must be stress relieved and heat treated for proper strength. Rotors must be dynamically balanced to ensure vibration-free operation.

2.2.6.4 Gears

Gears must be of alloy steel, ANSI/AGMA 2009 and AGMA 2011 Quality Number 12 or better for both bull and pinion gears. Gears must be hardened to 275 Brinell for bull gear and 320 Brinell for pinion, unless otherwise approved. Gears must be ground to the required contours, checked for proper contact during assembly at the factory, and must not require a break-in period in the field for proper operation. All gears must be pressure lubricated.

Timing gears must be provided on the rotor shafts to maintain the rotors in correct relative position. The compressor design must allow the timing gears to absorb no more than 10 percent of the total input power at full load.

2.2.6.5 Seals

Separate air and oil shaft seals must be provided to confine air in the casing and prevent contamination of the air stream by lubricating oil. Shaft seals must be the restrictive ring type. The seal rings must be stainless steel, brass, or carbon, and retainers must be made of stainless steel. Provide an air space vented to the atmosphere between the air and oil seals. Seals must be suitable for all operating conditions including suction throttling, start-up, and shutdown.

2.2.6.6 Thrust Bearings

Thrust bearings must be anti-friction ball or roller type or hydrodynamic (fluid film) type. Anti-friction bearings must have an L-10 life of 80,000 hours in accordance with ABMA 9 or ABMA 11. Axial rotor thrusts due to air compression must be absorbed by main thrust bearings or transferred to auxiliary thrust bearings by a load balancing arrangement. Hydrodynamic thrust bearings must be Kingsbury type or other approved type and must be adequate to accommodate all operating conditions. Speed increaser bull gear thrust bearings must be sized for equal thrust in both directions and must be adequate for any axial loads transmitted through the driver coupling.

2.2.6.7 Radial Bearings

Radial bearings must be anti-friction roller or ball type or hydrodynamic type. Anti-friction bearings must have an L-10 life of 40,000 hours in accordance with ABMA 9 or ABMA 11. Hydrodynamic bearings must be precision bored sleeve or pad type, designed for easy replacement by a split design or axially removable arrangement. High speed hydrodynamic pinion bearings must be anti-oil whip, tilting pad type. Hydrodynamic bearing design must provide low vibration and sufficient damping at rated speed and all operating modes, including rated capacity and unloading down to 20 percent of unloaded power.

2.2.6.8 Speed Increaser

The speed increaser must be an integral part of the compressor unit and must include the main drive shaft and bull gear. The main drive shaft must be supported through anti-friction bearings.

2.2.6.9 Intercoolers, Aftercooler, Bypass Cooler, and Oil Coolers

Intercoolers, aftercooler, bypass cooler, and oil cooler must include

ASTM B111/B111M admiralty brass or other corrosion resistant tubes in ASTM B171/B171M admiralty or steel tube sheets and baffles for optimum cooling and fouling resistance using fresh water. Provide an intercooler between stages of compression factory assembled on unit base with piping. The aftercooler must be mounted on the unit base. Intercoolers, aftercooler, bypass cooler, and oil cooler must be factory tested at 1.5 times operating pressure. External intercoolers and aftercooler must be constructed in accordance with ASME BPVC SEC VIII D1 requirements and be ASME code stamped for 150 psig working pressure. Intercoolers and aftercooler must be capable of one piece bundle removal. Intercoolers and aftercooler must be equipped with an integral or direct connected moisture separator with condensate trap assembly. Design intercoolers and aftercooler for 20 and 15 degrees F approach, respectively; however, the approach temperature used to size the coolers must be reduced if required to meet aftercooler maximum air outlet temperature specified. Nonstandard coolers must be provided if required to meet the aftercooler maximum air outlet temperature requirement. All coolers must be of counter-flow design, with a fouling factor of 0.002 for both sides of the coolers.

2.2.6.10 Lubrication System

Include an integral sump, positive displacement pump, oil cooler, and twin filter\strainer (readily replaceable cartridges while operating). Provide a prelube lubrication oil pump for start-up and standby for hydrodynamic bearings or if required by the compressor design. System must be factory assembled and tested. Lubricating oil must conform to recommendations of the compressor manufacturer. Spray lubricate drive gear, anti-friction bearings, and timing gear in each stage. Pressure lubricate hydrodynamic bearings. Provide the oil sump with a level indicator and drain and fill connections.

- a. Prelubrication pump, if required, or motor-driven main lubrication pump must be sized by air compressor manufacturer for the requirements of the system, but must meet the following requirements. Pump must be positive displacement gear pump separately mounted with motor on a common base plate with drip lip and drain.
 - (1) Performance: Pump must have separate safety valve bypass set at 25 psi above peak expected pressure.
 - (2) Materials must be hardened steel gears and shaft, cast iron case, bronze bearings, mechanical seal.
 - (3) Flexible coupling with shaft guard must be provided, except that these items are not required for a close-coupled pump.
 - (4) Motor must be NEMA MG 1, Design A or B, Class B insulation, of open drip-proof type. Furnish combination type starter for motor.
- b. Lube Oil Heater: Provide thermostatically controlled electric heater in lubrication oil sump of sufficient capacity to heat up and maintain manufacturer's recommended oil temperature when unit is cold at 32 degrees F ambient. Provide low oil level indicator with light for protection of heater.

2.2.7 Electric Motors

2.2.7.1 Main Electric Drive Motor

The main drive motor for each compressor must be an induction, or a synchronous motor, 50 horsepower (hp), with a continuous service factor of 1.0. Size the motor so that the name plate hp rating is not exceeded under the entire range of operating conditions specified. Efficiency and losses must be determined in accordance with IEEE 112. Unless otherwise specified horizontal polyphase squirrel cage motors rated one to 125 horsepower must be tested by dynamometer Method B as described in Section 6.4 of IEEE 112. Motor efficiency must be calculated using Form B of IEEE 112 calculation procedures. Polyphase motors larger than 125 horsepower must be tested in accordance with IEEE 112 with stray load loss determined by direct measurement or indirect measurement (test loss minus conventional loss). The efficiency must be identified on the motor nameplate by the caption NEMA Nominal efficiency or NEMA Nom eff. Electrical service will be as specified. Motor must be designed for reduced voltage starting at 50 percent of full voltage, allowing for characteristics of the connected load, and must start without undervoltage tripping. Provide resistance temperature detectors (RTD) attached to or imbedded in motor winding for control system. The motor must meet the requirements of NEMA MG 1 with Class F insulation. Provide space heaters for protection of windings during motor shutdowns.

2.2.7.2 Accessory and Related Equipment Motors

Motors less than 1/2 hp must be single-phase induction motors and must conform to NEMA MG 1. Motors 1/2 through 5 hp must be three-phase induction motors and must conform to NEMA MG 1. Single-phase and three-phase motors must have bimetallic disk thermostats attached to or imbedded in the motor winding. Motors must have NEMA MG 1 Class B insulation.

2.2.8 Control Panel

Control unit panel must conform to NEMA ICS 6, floor or frame mounted, factory designed, and assembled, and must be provided complete. The panel must be fabricated of formed stretcher leveled sheet steel, reinforced, and assembled into a rigid unit. Gasketed access doors must be provided as required. Panel must be factory finish painted. The panel must meet NEMA 12, requirements.

- a. Panel must contain electric and safety control work required, including either alarm annunciator or individual labeled pilot lights arranged in a group. Panel must contain alarm device with light and silencing. Generalized arrangement in accordance with drawings.
- b. Panel must contain start and stop buttons (the latter with lockout feature), discharge air pressure gage, control test switch and lights, reset button, green unit running light, and control selector switch.
- c. Oil pressure gages must be mounted separately from panel.

2.2.9 Accessories

Required accessories include:

2.2.9.1 Control Valves

Pneumatically or hydraulically controlled valves on suction inlet of compressor and on bypass or vent line.

2.2.9.2 Intake Devices

Compressor air inlet must be piped to the outside of the building and consist of the following:

- a. Intake weather hood with rain hood and bird screen. Material must be galvanized steel or aluminum alloy, minimum 20 gage.
- b. Intake pipe, ASTM A36/A36M steel galvanized, 12 gage or Schedule 5 minimum, from intake weather hood to filter housing flange, welded construction.
- c. Filter housing by filter manufacturer to include filter frames, access door(s). Material for housing must be 0.065 inch thick, Class 5000 aluminum alloy. Unit must be rigid and free from distress with all seams sealed.
- d. Intake Pipe from Filter Enclosure to Compressor: Aluminum alloy ASTM B209, Alclad alloy 5052-H32 or equivalent, minimum 10 gage, flanged, welded with 5XXX welding rod using TIG method and including expansion bellows.

2.2.9.3 Outlet Connectors

Compressor air outlet flexible connection of stainless steel bellows with braided steel cover jacket, with stainless steel liner sleeve, 18-inch (457-mm) nominal length bellows, flanged ends, Class 150. If air bypass connects separately to the compressor from the outlet line, provide a second flexible connection of stainless steel bellows with braided jacket for the bypass.

2.2.10 Inlet Air Filters

Provide a three-stage filter system, complete with mounting racks (horizontal flow), interstage seals, and replaceable filters. Filter unit must be provided complete including enclosure or housing, and frames. Enclosure must be Class 5000 aluminum alloy with inlet and outlet flanges. Construction must be welded or, where welding is not practical, close riveted and caulked, weathertight, with access doors for filter replacement and cleaning. Access doors must be reinforced, fully gasketed with continuous flexible neoprene gaskets, corrosion-resistant continuous hinges and quarter-turn latches to ensure tightness. All internal ferrous surfaces, including galvanized, must receive a factory-applied epoxy prime and finish coat for corrosion resistance. Filters must consist of three separate stages and sized to fit the available space.

2.2.10.1 First-Stage

First-stage filter must be flat, 2 inch thickness, replaceable media, and rated for the required air quantity at 500 FPM nominal face velocity, friction clean 0.25 inch water gage, efficiency 98 percent of 15 microns and 90 percent of 5 microns.

2.2.10.2 Second-Stage

Second-stage filter must be deep pleated type, 9 inches nominal depth and rated for the required air quantity at 350 FPM nominal face velocity, friction clean 0.20 inch watergauge, efficiency 98 percent of 5 microns and 90 percent of 3 microns.

2.2.10.3 Third-Stage

Third-stage filter must be deep pleated type 12 inches minimum depth and rated for the required air quantity at 350 FPM nominal face velocity, friction clean 0.30 inch watergauge, efficiency 99.9 percent of 0.5 micron.

2.2.10.4 Filter Ratings

Filter media must be rated and listed UL Class 2. Filter efficiencies must be based on National Bureau of Standards (NBS) type discoloration gravimetric test method using atmospheric dust.

2.2.11 Bypass or Vent Line Silencer

A bypass or vent line silencer must be furnished with each compressor as selected by compressor manufacturer for sufficient noise attenuation to meet OSHA sound level criteria, but not greater than 84 dBA measured at an elevation of 5 feet, and 10 feet horizontally from silencer.

2.2.12 Sound Attenuating Enclosure

The compressor package, including the driver motor, must be contained within a noise reducing enclosure. Design of the enclosure must be such as to limit noise transmission to 84 dBA or less at a distance of one meter from the compressor in any direction.

2.2.12.1 Enclosure Frame

The enclosure frame must be designed to support the weight of the sound suppression panels and easily demountable. Connections to the base frame must be designed to allow the enclosure frame to be detached and lifted away without damage to the connections, enclosure frame or base frame, and to allow accessibility and replacement of any component.

2.2.12.2 Panels

The panels must be of rigid construction to allow repeated access without damage or distortion. Sound absorbing material must be mineral fiber, treated to preclude shedding of fibers. Other approved insulation may be used except that polyurethane foam must not be permitted. Top panels must be secured to the enclosure frame with quick disconnect fittings and fabricated to allow easy hand removal for maintenance. End and side panels must be hinged or lift out with positive closure latches. Panels must be designed to allow the maximum access area when opened. Provide acoustic seals as required. Controls and instrumentation mounted on the panels must have flexible connections for panel opening and disconnects for enclosure removal. Disconnects must be of the male-female plug type. Panels must split around all piping connections to allow enclosure removal without detaching piping. Controls must be visible and operable from outside the enclosure.

2.2.12.3 Ventilation

Fan(s) and sound baffled ventilation grilles must be provided as part of the enclosure. Ventilation must be sufficient to limit interior temperature to that required for cooling the motor.

2.2.13 Isolating Pad

If specifically recommended by the compressor manufacturer, each compressor steel or iron base frame must be mounted on a neoprene waffle or rib type isolator pad which extends uniformly and continuously along the base mounting surface. The neoprene material must be of bridge bearing pad quality neoprene and must be formulated for 40 durometer hardness. The maximum bearing pressure on the isolating pad must be 50 psi. The pads must be composed of two layers or 5/16 inch neoprene bonded to and sandwiching 16 gage galvanized steel. Compressor bolt down through the pad must be accomplished using 1/4 inch thick neoprene impregnated duck washers. Neoprene bushings are not acceptable.

2.3 AIR FLOW RATE AND PRESSURE RECORDER AND MEASUREMENT

Provide a complete flow and pressure measurement and recording package. Provide orifice flanges with pressure taps, square edged stainless steel paddle orifice plate. The orifice plate must be concentric type, of 0.125 inch thickness and must meet ASME Standards. Orifice must be sized for 40 inch water column differential at a full scale flow rate of 235 SCFM at compressor based on 120 psig upstream pressure. Static gage pressure measurement device of the recorder must have a range of zero to 200 psig. Provide copper interconnecting tubing between the pressure taps and the recorder as part of this measurement and recording package. Provide a two-pen recorder for the measurement station. Pens must record pressure (0 to 200 psig range) and air flow (0 to 300 SCFM). Recorder must be electric drive and housed in dust-tight steel cabinet. Charts must be 12 inch diameter with evenly divided graduations. Drive must be 7 day circle. Provide continuous flow integration of a 7 digit counter type. Pens must be supplied with long-life cartridges and capillary supply. Chart case must be internally illuminated. Access to charts must be through front access window door. Calibrated overall accuracy of the recorded measurements must be within plus or minus 1.0 percent of full scale. Furnish a supply of 400 charts with the recorder.

2.4 CARBON MONOXIDE MONITOR

The carbon monoxide (CO) monitor unit must be of the pressure type with attached sampling system. The unit must be solid state type operation, 2 to 50 ppm range, CO indicating, with provisions for milliamp signal to remote recorder, adjustable set point, and normally open/normally closed contacts for remote signal. Power must be 120 volt, single phase, 60 hertz with power cord and plug. Response time normally 2 minutes per sample/purge. Unit must be mounted in a gasketed enclosure with face gage indicating CO readings.

2.4.1 Sampling System

Sampling system must include shutoff valve filter/regulator, pressure gage, manual drainer, and line humidifier set at 50 percent. Draw sample from compressor discharge.

2.4.2 Test System

Test system must include calibration gas (20 ppm CO) cylinder test gas (200 ppm CO) cylinder, and calibration connectors with quick disconnect.

2.5 SOURCE QUALITY CONTROL

2.5.1 Factory Test Procedures

The completely assembled air compressor package including the actual contract drive motor, intercooler, lubrication system, and control panel must be subjected to performance tests and sound level and run-in tests. Unit must comply with guarantee requirements applying engineering adjustments to guarantee conditions. Test must be certified by the manufacturer. Test may be run on the manufacturer's test stand using driver for this contract. Tests must be in accordance with ASME PTC 9 format. Full-range performance tests must indicate performance at maximum rated flow, rating point, and unloaded conditions. Motor performance conditions must be reported, including motor efficiency and losses, motor power factor, motor service factor, motor temperature rise, motor noise and balance, and motor torque at full load, locked rotor, pull up, and break down. Include intercoolers, aftercoolers, and lubrication and control systems performance. Completed unit must be factory tested with sound meters in accordance with ISO 2151. Location must be one horizontal meter from unit at 1.5 meters above the floor. Test must include readings at each octave band midpoint and the "A" scale, and must not exceed 84 dBA and 90 decibels at any octave band. Results of test must be included in the factory test report on the ISO 2151 format. Factory test data may be corrected to the levels of an equivalent background noise level of 60 dBA showing calculations for reference use.

2.5.2 Supervision of Testing

System and components testing must be conducted or supervised by either a designated authorized and factory trained representative of the compressor manufacturer supplying the unit or a registered Mechanical Engineer experienced in such work.

2.5.3 System Test

Testing of system must conform to requirements outlined and must be witnessed by the Contracting Officer.

2.5.4 Approval of Testing Procedure

Proposed testing procedure must be approved by the Contracting Officer and the individual in charge of testing prior to conducting tests.

2.5.5 Certification of Performance Tests

The test supervisor must certify performance by test to be in compliance with specifications.

PART 3 EXECUTION

3.1 INSTALLATION

The Contractor must install the air compressors and accessories in accordance with manufacturer's recommendations and as indicated on the

drawings. All equipment must be installed plumb and level and anchored to structure, matching holes provided. Install the compressor under the direct supervision of an authorized representative of the manufacturer.

3.2 GENERAL REQUIREMENTS FOR INSTALLING AIR COMPRESSORS

Air compressors with contract motor and accessories must be factory assembled, run in, and tested complete before shipment to job site. Should the unit require disassembly for installation, reassembly must be under the direct supervision of the compressor manufacturer's authorized representative. Complete unit must be mounted on a rigid single or equivalent mechanically joined steel or iron base. Submit installation sequence plans to the Contracting Officer for approval prior to installation.

3.2.1 Prompt Installation

The Contractor is advised that any compressor received must be installed and placed in operation promptly to prevent time deterioration when not installed. Should the Contractor sustain a delay exceeding 90 days prior to actual installation, the Contracting Officer must have the option of requiring breakdown and reassembly to inspect and clean prior to placing in operation. This work must be at no additional cost to the Government.

3.2.2 Start-Up Services

The Contractor must furnish the services of a compressor manufacturer's authorized representative to supervise prestart checkout, initial start-up, performance testing, and operator instruction. Time available must be as required to properly start up but not less than 3 consecutive days for the compressor.

3.3 FIELD QUALITY CONTROL

3.3.1 Field Test Procedures

Complete field performance testing of the total system must be performed by the Contractor and witnessed by the Contracting Officer. Air compressor system test must be conducted by either a compressor manufacturer's factory trained and authorized representative approved by the Contracting Officer or a qualified registered Mechanical Engineer. Tests may be run on individual components or on the system as a whole at Contractor option. Field tests require use of the actual compressor drive motor. Test must include operation at rated capacity for not less than 4 hours.

3.3.1.1 Air Compressor Performance Tests

Complete performance test must be run at maximum load, rated load, at point of unload but prior to unload, and unloaded condition. Data must be recorded listing:

- a. Air flow, inlet pressure and temperature, humidity; discharge pressure and temperature.
- b. Intercooler water flows, temperatures, and pressures.
- c. Aftercooler water flow, temperatures, and pressures.

- d. Bypass cooler water flow, temperatures, and pressures.
- e. Lube oil cooling water flow, temperatures, and pressures.
- f. Lube oil flow, pressures, and temperature.

- i. Electrical load in volts and amperes for compressor motor (loaded and unloaded), prelube oil pump motor, and compressor auxiliaries.
- j. Intake filter pressure differential (clean).
- k. Start-up sequence, alarm signals and automatic system shutdown.
- l. Test compressor intake and discharge for conformance to CGA G-7.1. Compressor discharge must show no increase in contaminants.

3.3.1.2 Instrumentation Test

The Contractor may use instrumentation provided in the contract and instrumentation provided by the Contractor to conduct the test. The testing procedure and instrumentation must be submitted to the Contracting Officer for approval prior to conducting tests. The format of ASME PTC 9 is required. It is intended that a full field test be performed. However, in lieu of precise instrumentation, the Contractor may use certified cooling water pump curves. Shutdown signals must be caused by throttling selected fluids. Test data, such as air intake temperature and humidity, must be mathematically corrected to performance test requirement levels.

3.3.1.3 Sound Level Tests

Sound level tests must be conducted concurrently. Broad Band "A" scale readings and Octave Band readings must be taken and recorded at the same positions as on the factory testing. Maximum permissible level must be 84 decibels one horizontal meter from the compressor and 1.5 meters above the floor, with unit in operation and all other significant equipment not required for test within the same building bay shutdown at the same location previously described. A background noise correction to 60 decibels is permissible.

3.3.1.4 Operational Deficiencies

Any operational deficiencies noted in the tests must be promptly corrected and affected portions of the test rerun.

3.3.1.5 Testing Tolerances

A tolerance of plus or minus 2 percent on flow, plus or minus 4 percent on power, or plus or minus 5 percent on any other variable for each item of equipment or fluid with all others conforming is permissible on field test results when compared to factory test data and to guarantee performance data except that compressor air flow, discharge pressure, and motor power must be met.

3.3.2 Approval of Testing Procedure

Proposed testing procedure must be approved by the Contracting Officer and the individual in charge of testing prior to conducting tests.

3.4 TRAINING OF GOVERNMENT PERSONNEL

During start-up and field testing, train Government station personnel in the operation and maintenance of compressor, associated equipment, and all control and safety devices. Training must not commence until equipment is operational and station personnel are in attendance. At least one day of classroom training and one day of field training must be furnished for each designated Government personnel. When factory training is required by the compressor manufacturer for proper maintenance and overhaul of the compressors, such training must be furnished by the compressor manufacturer at no additional cost to the Government. The Government will bear the cost of travel and living expenses for Government personnel as necessary for the factory training.

-- End of Section --

SECTION 22 15 26.00 20

HIGH AND MEDIUM PRESSURE COMPRESSED AIR PIPING

04/06

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR-CONDITIONING, HEATING AND REFRIGERATION INSTITUTE (AHRI)

ANSI/AHRI 520 (2004) Performance Rating of Positive Displacement Condensing Units

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B1.20.1 (2013; R 2018) Pipe Threads, General Purpose (Inch)

ASME B16.9 (2018) Factory-Made Wrought Buttwelding Fittings

ASME B16.11 (2022) Forged Fittings, Socket-Welding and Threaded

ASME B16.20 (2023) Metallic Gaskets for Pipe Flanges

ASME B16.34 (2021) Valves - Flanged, Threaded and Welding End

ASME B16.39 (2020) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300

ASME B31.1 (2022) Power Piping

ASME B40.100 (2022) Pressure Gauges and Gauge Attachments

ASME B46.1 (2020) Surface Texture, Surface Roughness, Waviness and Lay

ASME BPVC SEC IX (2017; Errata 2018) BPVC Section IX-Welding, Brazing and Fusing Qualifications

ASME BPVC SEC VIII D1 (2019) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M (2020; Errata 1 2021) Structural Welding Code - Steel

AWS Z49.1 (2021) Safety in Welding and Cutting and Allied Processes

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M (2022) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

ASTM A106/A106M (2019a) Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service

ASTM A182/A182M (2024) Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service

ASTM A193/A193M (2023) Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service and Other Special Purpose Applications

ASTM A194/A194M (2023) Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both

ASTM A380/A380M (2017) Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems

ASTM B127 (2019) Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip

ASTM B164 (2003; R 2014) Standard Specification for Nickel-Copper Alloy Rod, Bar, and Wire

ASTM E11 (2022) Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

ASTM E381 (2022) Standard Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-58 (2018) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation

MSS SP-69 (2003; Notice 2012) Pipe Hangers and Supports - Selection and Application (ANSI Approved American National Standard)

MSS SP-71 (2018) Gray Iron Swing Check Valves, Flanged and Threaded Ends

MSS SP-80 (2019) Bronze Gate, Globe, Angle and Check Valves

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 2 (2000; R 2020) Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 V

NEMA ICS 6 (1993; R 2016) Industrial Control and Systems: Enclosures

NEMA MG 1 (2021) Motors and Generators

NATIONAL FLUID POWER ASSOCIATION (NFLPA)

ANSI/NFLPA T3.12.3 (1992; Rev 2) Pneumatic Fluid Power - Pressure Regulator - Industrial Type

PIPE FABRICATION INSTITUTE (PFI)

PFI ES 22 (2016) Recommended Practice for Color Coding of Piping Materials

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)

SMACNA 1981 (2008) Seismic Restraint Manual Guidelines for Mechanical Systems, 3rd Edition

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-C-15726 (1988; Rev F; Am 1 1991; Notice 1 2020) Copper-Nickel Alloy, Sheet, Plate, Strip, Bar, Rod, and Wire

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

CID A-A-1689 (Rev B) Tape, Pressure-Sensitive Adhesive, (Plastic Film)

CID A-A-58092 (Basic; Notice 1; Notice 2) Tape, Antiseize, Polytetrafluoroethylene

CID A-A-60001 (Rev A) Traps, Steam

FS WW-S-2739 (Basic; Notice 1; Notice 2) Strainers, Sediment: Pipeline, Water, Air, Gas, Oil, or Steam

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

29 CFR 1910.219 Mechanical Power Transmission Apparatus

1.2 RELATED REQUIREMENTS

Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND METHODS, applies to this section, with the additions and modifications specified herein.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

High Pressure Compressed Air System

SD-03 Product Data

Air Compressor

Air Dryer

Air Receivers

Desiccant Air Dryers

Fittings

Valves

Pressure gages

Traps

Strainers

Unions

Flexible connections

Hangers and Supports

Valve box

Identification Labels For Piping

For receivers include Manufacturer's Data Report Form U-1 or U-1A.

SD-06 Test Reports

Non-Destructive Examination (NDE) Report For Welding of Piping

Leak Tightness Test

SD-07 Certificates

Employer's Record Documents

Welding Procedures and Qualifications

SD-08 Manufacturer's Instructions

Air receivers

Include recommended certification test procedure and procedure for cleaning, external painting, and delivery preparation.

SD-10 Operation and Maintenance Data

Air Compressor, Data Package 4

Air Dryer, Data Package 4

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

SD-11 Closeout Submittals

Posted Operating Instructions for Air Compressor

Posted Operating Instructions for Air Dryer

Posted Operating Instructions for Compressed Air Systems

1.4 QUALITY ASSURANCE

Provide all work specified in this section, including design, materials, fabrication, assembly, erection, installation, and examination, inspection and testing of compressed air systems in conformance with ASME B31.1, ASME BPVC SEC VIII D1 ASME BPVC SEC IX and SMACNA 1981, as modified and supplemented by this specification section and accompanying drawings. In ASME B31.1, ASME BPVC SEC VIII D1 and ASME BPVC SEC IX, the advisory provisions must be considered mandatory, as though the word "must" had been substituted for "should" wherever it appears; reference to the "authority having jurisdiction" and "owner" must be interpreted to mean the Contracting Officer.

1.4.1 Equipment Data

Submit the following data for equipment listed for "Operation and Maintenance Instructions, Parts and Testing."

- a. Name and address of authorized branch or service department.
- b. Characteristic curves.
- c. Following applicable data completely filled in:

Manufacturer and model number

Operating speed

Capacity (CFM)

Type of bearings in unit

Type of lubrication

Type and adjustment of drive

Capacity of tank

Electric motor: Manufacturer, frame and type

Motor speed RPM

Current characteristics and HP of motor Thermal cut-out switch:
Manufacturer, type and model

Starter: Manufacturer: Type and model

1.4.2 High Pressure Compressed Air System

Show location, length, and type of welds or brazes, and indicate welding and brazing procedures to be used, preheat, postweld heat treatment, and nondestructive welding and brazing testing required.

1.4.3 Laboratory Test Reports and Material Control

Laboratory Test Reports and Material Control for high Pressure Compressed Air Systems:

1.4.3.1 Laboratory Test Reports

Furnish the following laboratory test reports for pipe, tube, fittings, valves, and other pressure containing components (except pressure gages) for each heat and lot of material.

- a. Full chemical analyses.
- b. Physical properties.
- c. Etch test per ASTM E381 as modified for the alloy to verify pipe and tube are seamless and free of defects.

1.4.3.2 Material Control

Where more than one type of corrosion resistant alloy (stainless steel and copper-nickel or nickel-copper for example) is to be installed at project site, the Contractor must implement and maintain a material control system with markings and/or tags to identify positively each piece as to the type of metal.

1.4.4 Welding Requirements

Provide all welding work specified in this section for compressed air piping systems and in conformance with ASME B31.1, as modified and supplemented by this specification section and the accompanying drawings. The welding work includes: qualification of welding procedures, brazing procedures, welders, brazers, welding operators, brazing operators, inspection personnel, nondestructive examination personnel, maintenance of welding records, and examination methods for welds.

1.4.4.1 Butted Welded Joints

Butt welded joints must be full penetration joints. Butt welded joints in systems with working pressures over 300 psig must be full penetration welds with consumable inserts or backing rings.

1.4.5 Employer's Record Documents

Submit to the ROICC for his review and approval the following documentation. This documentation and the subject qualifications must be in compliance with ASME B31.1.

- a. List of qualified welding procedures that is proposed to be used to provide the work specified in this specification section.
- b. List of qualified welders, brazers, welding operators, and brazing operators that are proposed to be used to provide the work specified in this specification section.
- c. List of qualified weld inspection personnel that are proposed to be used to provide the work specified in this specification section.

1.4.6 Welding Procedures and Qualifications

Determine performance qualification in accordance with ASME B31.1 and as specified.

1.4.6.1 Specifications and Test Results

Submit copies of the welding procedure specifications and procedure qualification test results for each type of welding required. Approval of any procedure does not relieve the Contractor of the responsibility for producing acceptable welds. Submit this information on the forms printed in ASME BPVC SEC IX or their equivalent.

1.4.6.2 Certification

Before assigning welders or welding operators to the work, submit a list of qualified welders, together with data and certification that each individual is performance qualified as specified. Do not start welding work prior to submitting welder, and welding operator qualifications. The certification must state the type of welding and positions for which each is qualified, the code and procedure under which each is qualified, date qualified, and the firm and individual certifying the qualification tests.

1.4.6.3 Renewal of Qualification

Requalification of a brazer or brazing operator must be required under any of the following conditions:

- a. When a brazer or brazing operator has not used the specific brazing process for a period of 6 months.
- b. There is specific reason to question his ability to make brazes that will meet the requirements of the specifications.

1.4.7 Experience for Installation and Testing

Experience for Installation and Testing Of Medium Pressure Air System: Install and test medium pressure air piping and equipment in accordance with ASME B31.1 and only with competent personnel specially trained and experienced in installation and testing of medium pressure air systems. The supervisors and personnel performing installation and testing must

have had previous experience in the satisfactory installation and testing of at least two medium pressure air systems. Submit data substantiating this experience to the Contracting Officer for approval prior to performing any work. Supervisors and personnel with experience not acceptable to the Contracting Officer will be prohibited from working on these systems. Experience data must include the following.

- a. Name of employee
- b. Employer
- c. List educational background and specialized training on installation and testing medium pressure systems, including safety precautions.
- d. List at least two installations of each type of system worked on and installed and tested satisfactorily.
 - (1) Type of system and operating or design pressure; for medium pressure 126 to 399 psig; for high pressure 400 psig and higher.
 - (2) Company or owner.
 - (3) Location.
 - (4) Name, address, and phone number of a person who can be contacted for verification at the installation.
- e. If registered engineer, give the state in which registration is held, and branch of engineering. An engineer is required to supervise safety during testing of medium and high pressure air systems.

1.4.8 Qualification of Pressure Vessel (Receiver) Inspectors

State Certification of Competency and active commission from the National Board of Boiler and Pressure Vessel Inspectors (NBBI), Columbus, Ohio.

1.4.9 Training

Where special cleaning, flushing, material control, testing, and other special requirements are used on a contract, such as required for high pressure compressed air systems, conduct formal training programs for employees on the special requirements. Maintain records on such training which must be available for inspection by the Contracting Officer. Certify that employees have satisfactorily completed the required training prior to performing work on the contract.

1.5 SAFETY PRECAUTIONS

1.5.1 Temperature Restriction

Compressors or other equipment must not discharge compressed air to the piping systems above 100 degrees F unless approved by the Contracting Officer. Aftercoolers or other devices must be provided to comply with the temperature restriction.

1.5.2 Rotating Equipment

Fully guard couplings, motor shafts, gears and other exposed rotating or rapidly moving parts in accordance with OSHA 29 CFR 1910.219. Provide

rigid and suitably secured guard parts readily removable without disassembling guarded unit.

1.5.3 Welding and Brazing

Safety in welding, cutting, and brazing of pipe must conform to AWS Z49.1.

PART 2 PRODUCTS

2.1 MEDIUM PRESSURE AIR COMPRESSOR

126 to 399 psig system. Multi-stage, air cooled reciprocating, direct driven type, suitable for supplying compressed air at pressures indicated. Provide compressor with ball or roller type bearing, pressure lubricated, thermal overload protection as required by NEMA, pressure switch, inlet filter-mufflers, vibration isolators, intercoolers, aftercooler, and flexible connectors. Provide safety control for shutdown and alarm on high discharge air temperature or low oil pressure. Capacity and operating pressure as indicated on drawings. Mount compressor and motor on a base plate.

2.1.1 Receiver

Build receiver (tank) of welded steel, in accordance with ASME BPVC SEC VIII D1, Unfired Pressure Vessels, for 399 psig working pressure at 450 degrees F, complete with pressure gage, ASME BPVC SEC VIII D1 and ASME BPVC SEC IX code stamped safety valve, check valve, shut-off valve on tank outlet, and automatic tank drain on tank. Provide tank with steel supports and bolt to a concrete foundation. Capacity as indicated.

2.1.2 Motor and Starter

Provide motor and starter 72 degrees F ambient temperature rise, continuous duty, drip-proof type motor, ball bearings, for operation with current of voltage, phase, and cycle indicated on the electrical drawings. Motor of such capacity that brake horsepower required by driven equipment at normal rated capacity will not exceed nameplate rating of motor. Provide each motor with automatic, fully enclosed, magnetic starter. Conform to NEMA MG 1 for motor and NEMA ICS 2 and NEMA ICS 6 for starter and controls.

2.1.3 Controls

Provide start-and-stop control. Motor must stop automatically when discharge pressure reaches maximum pressure setting and start automatically when discharge pressure falls to minimum setting. Cylinders must unload automatically during periods of motor shutdown.

2.1.3.1 Start-and-Stop Control

When set for start-and-stop control, motor must stop automatically when discharge pressure reaches maximum pressure setting and start automatically when discharge pressure falls to minimum setting. Cylinders must unload during periods of motor shutdown.

2.1.3.2 Constant Speed Control

Compressor must operate continuously at constant speed. Provide means to automatically load and unload compressor at preset minimum and maximum pressure settings, respectively. Provide means for automatic release of pressure within cylinders when the unit is operating without load. Also provide means for manual or automatic unloading of cylinders during starting of unit. Equip compressor with a timed control to stop compressor after a 10-minute unloaded period if air is not used.

2.1.4 Intercoolers and Aftercoolers

Provide intercoolers between all intermediate stages of multi-stage compressors and provide aftercoolers with compressors. Intercoolers for air-cooled compressors must be the tube-and-fin type. Intercoolers for water-cooled compressors must be the shell-and-tube type, except that tube-and-fin type may be used when the intercooler is supported by the compressor frame or attached to the compressor. Air or water cooled intercoolers may be the integral cast type when compressor is 25 hp or less. Aftercoolers must be of the water-cooled shell-and-tube type or air-cooled tube-and-fin type. Water-cooled aftercoolers and intercoolers must be of sufficient capacity to cool the compressed air to within 15 degrees F and 20 degrees F, respectively, of the temperature of the water entering the coolers. Air-cooled intercoolers and aftercoolers must have sufficient capacity to cool the compressed air to within 20 degrees F of the ambient temperature under the atmospheric conditions indicated. Provide water-cooled intercoolers and aftercoolers with sight-flow indicator to visually observe the flow of water to the cooler. The pressure drop of compressed air through the cooler must not exceed one psi. Provide intercoolers and aftercoolers with a moisture separator and drain trap to remove the condensed moisture and oil from the air leaving the cooler.

2.1.4.1 Shell-and-Tube

Floating-head type consisting of a removable and cleanable nest of corrosion-resistant tubes within a steel shell. Air may pass either through the tubes or the shell.

2.1.4.2 Tube-and-Fin

Copper, aluminum, copper-aluminum, or copper-alloy construction. Fins must be securely bonded to the tubing. Provide tube-and-fin coolers with a fan for circulation of the cooling air. The fan must be adequately guarded for safety and be driven either from the compressor crankshaft or by an independent electric motor.

2.1.5 Noise

84 dBA maximum sound level one meter from compressor unit.

2.2 MEDIUM PRESSURE Air receivers

ASME BPVC SEC VIII D1, labeled and rated for 275 psig, equipped with required valves and trimmings, including gage and automatic drain valve and ASME BPVC SEC VIII D1 and ASME BPVC SEC IX pressure safety relief valve. Pressure as indicated. Exterior finish must be standard factory finish .

2.3 MEDIUM PRESSURE COMPRESSED AIR DRYERS

Provide medium pressure compressed air dryers of the mechanical refrigeration type, equipped with an automatic temperature shutdown switch to prevent freezing, a regenerative air to air exchanger (in capacity sizes above 10 or 60 scfm as standard with the manufacturer), and a main compressed air cooling exchanger. Refrigeration system must cool compressed air to dry the air. Dryer must have no internal traps or filters and must have pressure drop not greater than 3 psi . Provide internal tubing, wiring, and piping complete, such that only connections to air inlet and outlet, to refrigerant compressor contactor, and to condensate drain are necessary.

2.3.1 Air Circuit

- a. Regenerative heat exchanger: Inlet compressed air to outlet compressed air heat exchanger (in capacity sizes above 10 or 60 scfm as standard with the manufacturer) designed to reduce cooling load at design conditions 20 degrees F by inlet air precooling.
- b. Main heat exchanger: Single-pass, with air in the tubes, heat sink, direct expansion, or flooded cooler type.
- c. Separator: Fabricated in accordance with ASME B31.1; code stamp not required; moisture separator low velocity type incorporating change of air flow direction to prevent moisture carryover.
- d. Dryer operating pressure: 275 psig working pressure.
- e. Drain line: Provide with exterior mounted condensate trap to facilitate servicing.

2.3.2 Refrigeration System

- a. Refrigeration compressor: ANSI/AHRI 520. Hermetic, semi-hermetic, or open reciprocating type equipped with automatic start-stop or unloading capacity control; standard components include inherent motor protection, crankcase oil strainer, and suction screen. .
- b. Dryer controls: Capable of automatic 0 to 100 percent capacity control. Refrigeration controls must maintain pressure dew point within the specified range without freezing of condensate. Controls must include such devices as capillary tube, expansion valve, suction pressure regulator, thermostat, or other approved devices as standard with the manufacturer. Dryer must have automatic shutdown switch sensor located at point of lowest temperature to prevent freezing.
- c. Refrigerant dryer and suction line strainer.
- d. Air-cooled condenser, with condenser fan and motor.

2.3.3 Instrumentation and Control

Include control panel in dryer cabinet containing:

- a. Indicators for the following services: Inlet air pressure gage, discharge air pressure gage, inlet air temperature gage, main exchanger temperature gage, refrigeration compressor suction pressure gage, refrigeration compressor discharge pressure gage, green "Power

On" light, power interruption light, and high temperature light.

- b. Electrical relays: Locate in an enclosed portion of the panel, accessible for ease of servicing.
- c. Controls and interlocks: To maintain required compressed air dew point and to cycle air-cooled condenser with refrigeration compressor while maintaining head pressure control with low ambient temperature.

2.4 DESICCANT AIR DRYERS

Chamber of welded steel, psig working pressure, ASME labeled conforming to ASME BPVC SEC VIII D1, with flanged or threaded fittings, and automatic drain valve. Manufacturer's recommended desiccant in tablet form which will not nest or cake. Contractor must provide a supply of desiccant for initial operations in unbroken shipping containers equal to not less than four charges of desiccant for the dryer.

2.5 MEDIUM PRESSURE COMPRESSED AIR PIPING AND ACCESSORIES

Medium pressure compressed air piping and accessories 126 to 399 psig at 150 degrees F must conform to the following:

2.5.1 Pipe

ASTM A53/A53M or ASTM A106/A106M, seamless carbon steel, Schedule 40, black.

2.5.2 Fittings, Size 2 Inches and Larger

ASME B16.9, carbon steel, butt welding, Schedule 40, or ASME B46.1, carbon steel welding neck flanges, Class 300, ASME B46.1, flanged fittings, carbon steel, Class 300, gaskets ASME B16.20, spiral wound metallic, Class 300, bolts ASTM A193/A193M, Grade B7, and nuts, ASTM A194/A194M, Grade 7. Butt welded joints must be full penetration consumable insert or backing ring type.

2.5.3 Fittings, Size 1 1/2 Inches and Smaller

ASME B16.11, forged carbon steel, Class 3000 socket welding or Class 2000 threaded. Seal weld threaded joints not required to disassemble piping for maintenance. Joints may also be butt welded or flanged, as specified for sizes 2 inches and larger.

2.5.4 Flat-faced Steel Flanges

Where connections are made to Class 250 cast iron flanges with steel flanges, use only flat-faced Class 300 steel flanges.

2.5.5 Unions

ASME B16.39, Class 2 (500 psig WOG, cold, non-shock).

2.5.6 Valves

2.5.6.1 Globe and Angle Valves

Sizes 2 inches and smaller, bronze, MSS SP-80, Type 3 (Metallic Disc, Renewable Seat), Class 300, threaded ends, or carbon steel, ASME B16.34,

Class 300, threaded ends. Sizes larger than 2 inches, ASME B16.34, carbon steel, tapered disk, Class 300, flanged ends.

2.5.6.2 Check Valves

ASME B16.34 or MSS SP-71, Class 300, steel, lift or swing type.

2.5.6.3 Pressure Reducing Valves

ANSI/NFLPA T3.12.3, with nominal pressure rating of not less than inlet system pressure indicated. Provide pressure reducing valves capable of being adjusted to specified flow and pressure, and suitable for intended service. Provide pilot valve for dome loaded type if required for proper operation.

2.5.6.4 Safety Valves

ASME BPVC SEC VIII D1 and ASME BPVC SEC IX, Code stamped safety valve, bronze body with bronze trim, for unfired pressure vessels, threaded or flanged connection; factory set and sealed.

2.5.7 Pressure Gages

ASME B40.100, Accuracy Grade A, for air, with steel or brass case, and nonshatterable safety glass, and a pressure blowout back to prevent glass from flying out in case of an explosion. Gages must have a 3 1/2 inch minimum diameter dial and a dial range of approximately twice working pressure.

2.5.8 Pipe Hangers and Supports

MSS SP-58, MSS SP-69, and ASME B31.1, except as specified or indicated otherwise. Provide zinc plated pipe hangers and supports. Provide tubing supports of U-shaped steel bolts and nuts firmly secured to adequately support structures such as walls, columns, floors, or brackets. Clips must fit closely around piping but must have sufficient clearance to permit longitudinal movement of piping during normal expansion and contraction. Provide supports at valves, fittings, branch lines, outlets, changes in direction, equipment, and accessories.

2.5.9 Strainers

FS WW-S-2739, Class 250, Style Y, simplex type, with 20-mesh Monel or stainless steel screen.

2.5.10 Traps

CID A-A-60001, to drain water and other liquids from system. Type of traps, as indicated, and rated working pressure not less than system operating pressure.

2.5.11 Flexible Connections

Vibration isolation, wire braid reinforced corrugated metal hose type, line-sized, with bronze end connections, suitable for pressure indicated. Length as recommended by manufacturer but not less than 18 inches.

2.5.12 Tetrafluoroethylene Tape

CID A-A-58092 for screw-jointed pipe.

2.6 SLEEVES

2.6.1 Floor Slabs, Roof Slabs, and Outside Walls Above and Below Grade

Galvanized-steel pipe having an inside diameter at least 1/2 inch larger than the outside diameter of the pipe passing through it. Provide sufficient sleeve length to extend completely through floors, roofs, and walls, so that sleeve ends are flush with finished surfaces except that ends of sleeves for floor slabs must extend 1/2 inch above finished floor surface. Sleeves located in waterproofed construction must include flange and clamping ring.

2.6.2 Partitions

Galvanized sheet steel, 26 gage or heavier, of sufficient length to completely extend through partition thickness with sleeve ends flush with partition finished surface.

2.7 VALVE BOX

Provide rectangular concrete design with words "Compressed Air" cast or otherwise marked on the cover. Size must be large enough for removal of valve without removing box. Provide valve box for areas as follows:

- a. Roads and traffic areas: Heavy Duty, cast iron cover
- b. Other areas: Standard duty, heavy steel plate or concrete cover

2.8 IDENTIFICATION LABELS FOR PIPING

Labels for pipes 3/4 inch O.D. and larger must bear printed legends to identify contents of pipes and arrows to show direction of flow. Except that of pipes smaller than 3/4 inch O.D., labels must have color coded backgrounds to signify levels of hazard in accordance with PFI ES 22. Legends and type and size or characters must also conform to PFI ES 22. Labels must be made of plastic sheet in conformance with CID A-A-1689 with pressure-sensitive adhesive suitable for the intended applications or they may be premolded of plastic to fit over specific pipe outside diameters 3/4 inch and larger. For pipes smaller than 3/4 inch O.D., furnish brass identification tags 1 1/2 inches in diameter with legends in depressed black-filled characters.

2.9 BURIED UTILITY WARNING AND IDENTIFICATION TAPE

Polyethylene plastic tape manufactured specifically for warning and identification of buried utility lines. Tape must be of the type provided in rolls, 6 inches minimum width, color codes for compressed air (gray) with warning and identification imprinted in bold black letters continuously and repeatedly over entire tape length. Warning and identification must be "CAUTION BURIED COMPRESSED AIR LINE BELOW" or similar wording. Code and letter coloring must be permanent, unaffected by moisture and other substances contained in trench backfill material.

2.10 FRESH WATER

Fresh water for cleaning, flushing, and testing must be clean and potable.

2.11 BASIC PIPING AND COMPONENT MATERIALS

Conform to the following where material is specified by generic type and no specification is listed.

2.11.1 Stainless Steel

Austenitic type, annealed, ASTM A182/A182M.

2.11.2 Nickel-Copper

70-30 nickel-copper, annealed, ASTM B164, alloy N04400, ASTM B127.

2.11.3 Copper-Nickel

70-30 copper-nickel, soft temper, MIL-C-15726.

2.11.4 Other Materials

For materials where no specification is listed above, conform to material specifications listed in ASME B31.1 or ASME BPVC SEC VIII D1.

2.12 SOURCE QUALITY CONTROL

Test air compressors and compressed air dryers at the factory to assure proper operation. Certify satisfactory accomplishment of tests.

PART 3 EXECUTION

3.1 INSTALLATION

Install materials and equipment as indicated and in accordance with manufacturer's recommendations.

3.1.1 Excavation and Backfilling

Section 31 00 00 EARTHWORK.

3.1.2 Piping

Provide Non-Destructive Examination (NDE) report for welding of piping. Unless specifically stated to the contrary, fabrication, assembly, welding, and brazing must conform to ASME B31.1 for all piping of the air system. Piping must follow the general arrangement shown. Cut piping accurately to measurements established for the work. Work piping into place without springing or forcing, except where cold-springing is specified. Piping and equipment within buildings must be entirely out of the way of lighting fixtures and doors, windows, and other openings. Locate overhead piping in buildings in the most inconspicuous positions. Do not bury or conceal piping until it has been inspected, tested, and approved. Where pipe passes through building structure, pipe joints must not be concealed, but must be located where they may be readily inspected and building structure must not be weakened. Avoid interference with other piping, conduit, or equipment. Except where specifically shown otherwise, vertical piping must run plumb and straight and parallel to

walls. Piping connected to equipment must be installed to provide flexibility for vibration. Adequately support and anchor piping so that strain from weight of piping is not imposed on the equipment.

3.1.2.1 Fittings

Use long radius ells where appropriate to reduce pressure drops. Pipe bends in lieu of fittings may be used for piping where space permits. Pipe bends must have a uniform radius of at least five times the pipe diameter and must be free from any appreciable flattening, wrinkling, or thinning of the pipe. Mitering of pipe to form elbows, notching straight runs to form full sized tees, or any similar construction must not be used. Make branch connections with welding tees, except factory made forged welding branch outlets or nozzles having integral reinforcements conforming to ASME B31.1 may be used.

Bending of High Pressure Pipe: Prior to bending pipe for high pressure systems, the Contractor must submit for approval written fabrication and inspection procedures and calculations showing the required minimum wall thickness of pipe after bending. Only cold bending must be permitted. The fabrication procedure must indicate the required pipe wall thickness prior to bending, equipment to be used, set up and bending procedures, and inspection and acceptance criteria. Inspection must include verification of minimum wall thickness by ultrasonic or other methods if deemed necessary by the Contracting Officer. No wrinkles or other contour irregularities will be permitted in the bent pipe. Check flattening in accordance with ASME B31.1. Include required dimensional checks in inspection procedures and acceptable values tabulated for each pipe size to be bent. Qualified personnel must perform nondestructive examinations required in accordance with qualified procedures.

3.1.2.2 Clearances for Welding

Provide clearances from walls, ceilings, and floors to permit the installation of joints. The clearances must be at least 6 inches for pipe sizes 4 inches and less, 10 inches for pipe sizes over 4 inches, and sufficient in corners. However, the specified clearances must not waive requirements for welders to be qualified for the positions to be welded.

3.1.2.3 Cleaning

Before jointing and erection of piping or tubing, thoroughly clean interiors of pipe sections, tube, and components. In steel pipe, loosen scale and other foreign matter by rapping sharply and expel by wire brush and swab. Blow out both steel pipe and copper tube and components with compressed air at 100 psig or more. Maintain cleanliness by closure of pipe/tube openings with caps or plugs. Before making final terminal connections, blow out complete system with compressed air at 100 psig or more. Cleaning and cleanness of medium pressure systems over 250 psig and high pressure systems must conform to the paragraph entitled "Cleaning and Cleanness Requirements."

3.1.2.4 Changes in Pipe Size

Use reducing fittings for changes in pipe size. The use of bushings will not be permitted. In horizontal lines, 2 1/2 inches and larger, reducing fittings must be of the eccentric type to maintain the bottom of the lines in the same plane.

3.1.2.5 Drainage and Flexibility

Compressed air piping must be free of unnecessary pockets and pitched approximately 3 inches per 100 feet in the direction of flow to low points. Where pipes must be sloped so that condensate flows in opposite direction to air flow, slope 6 inches per 100 feet or greater. Provide flexibility by use of fittings, loops, and offsets in piping. Install branches at top of a main to prevent carryover of condensate and foreign matter.

3.1.3 Threaded Joints

Where possible use pipe with factory cut threads, otherwise cut pipe ends square, remove fins and burrs, and cut taper pipe threads in accordance with ASME B1.20.1. Threads must be smooth, clean, and full cut. Apply thread tape to male threads only. Work piping into place without springing or springing or forcing. Backing off to permit alignment of threaded joints will not be permitted. Engage threads so that not more than three threads remain exposed.

3.1.4 Flanged Joints in High Pressure System

Install using calibrated torque wrenches or feeler gage methods to assure proper gasket compression. Calibrate torque wrench immediately prior to use.

3.1.5 Welding and Brazing

Perform welding and brazing in accordance with qualified procedures using qualified welders and welding operators and brazers. Do not perform welding and brazing when the quality of the completed weld or braze could be impaired by the prevailing working or weather conditions. The Contracting Officer will determine when weather or working conditions are unsuitable for welding. Welding of hangers, supports, and plates to structural members must be in accordance with AWS D1.1/D1.1M. Mark welding and brazing detail drawings to identify the welder or brazer making the joint.

3.1.5.1 Cleaning for Welding and Brazing

Surfaces to be welded or brazed must be free from loose scale, slag, rust, paint, oil, and other foreign material. Joint surfaces must be smooth and free from defects which might affect proper welding. Clean each layer of weld metal thoroughly by wire brushing, grinding, or chipping prior to inspection or deposition of additional weld metal. Conform to paragraph entitled "Cleaning and Cleanness Requirements" for medium pressure systems over 250 psig systems.

3.1.5.2 Stress Cracking During Brazing

For austenitic stainless steel and other material susceptible to stress corrosion cracking from molten brazing filler metal, avoid applying stress during brazing.

3.1.5.3 Welding or Brazing of Valves

Welding or Brazing of Valves: Disassemble valves subject to damage from heat during welding or brazing and reassemble after installation. Open valves two or three turns off the seat when not subject to heat damage

during welding or brazing; do not backseat valve.

3.1.6 Valves

Install valves in conformance with ASME B31.1 at the locations indicated and elsewhere as required for the proper functioning of the system.

3.1.6.1 Globe Valves

Install globe valves so that the pressure will be below the disk. Install globe valves with the stems vertical.

3.1.6.2 Pressure-Reducing Valves

Provide compressed air entering each pressure-reducing valve with a strainer. Provide each pressure-reducing valve unit with two block valves and with a globe or angle bypass valve and bypass pipe. Provide a bypass around a reducing valve of reduced size to restrict its capacity to approximately that of the reducing valve. Provide each pressure reducing valve unit with an indicating gage to show the reduced pressure, and a safety valve on the lower pressure side. These requirements do not apply to small pressure regulating valves used to adjust pressure for pneumatic equipment.

3.1.7 Hangers and Supports

Selection, fabrication, and installation of piping hangers and supports must conform to MSS SP-58, MSS SP-69 except that spacing of the hangers and supports must be as per Table I.

TABLE I. MAXIMUM SPAN FOR PIPE		
DIAMETER INCHES	STD. WT. STEEL PIPE SCHEDULE 40	EX. STRONG STEEL PIPE SCHEDULE 80
1/2	5'-0"	5'-0"
3/4	5'-9"	5'-9"
1	6'-6"	6'-6"
1-1/2	7'-6"	7'-9"
2	8'-6"	8'-6"
2-1/2	9'-3"	9'-6"
3	10'-3"	10'-6"
3-1/2	11'-0"	11'-0"
4	11'-6"	11'-9"
5	12'-9"	13'-0"

6	13'-9"	14'-0"
8	15'-6"	16'-0"
10	17'-0"	17'-6"
12	18'-3"	19'-0"

3.1.8 Pressure Gages

Provide pressure gauges with a shut-off valve or petcock installed between the gage and the line.

3.1.9 Strainers

Provide strainers with meshes suitable for the services where indicated, or where dirt might interfere with the proper operation of valve parts, orifices, or moving parts of equipment.

3.1.10 Equipment Foundations

Provide equipment foundations of sufficient size and weight and of proper design to preclude shifting of equipment under operating conditions or under any abnormal conditions which could be imposed upon the equipment. Provide foundations which meet the requirements of the equipment manufacturer, and when required by the Contracting Officer, obtain from the equipment manufacturer approval of the foundation design and construction for the equipment involved. Equipment vibration must be maintained within acceptable limits, and must be suitably dampened and isolated.

3.1.11 Equipment Installation

Install equipment strictly in accordance with these specifications, and the manufacturers' installation instructions. Grout equipment mounted on concrete foundations before piping is installed. Install piping in a manner that does not place a strain on any of the equipment. Do not bolt flanged joints tight unless they match properly. Extend expansion bends adequately before installation. Grade, anchor, guide and support piping without low pockets.

3.1.12 Cleaning of System

Clean the various system components before final closing as the installations are completed. Remove foreign matter from equipment and surrounding areas. Cleaning and cleanliness must conform to paragraph entitled "Cleaning and Cleanliness Requirements" for pressures over 250 psig. Preliminary or final tests will not be permitted until the cleaning is approved by the Contracting Officer.

3.1.13 Pipe Sleeves

Provide pipe sleeves where pipes and tubing pass through masonry or concrete walls, floors, roofs, and partitions. Hold sleeves securely in proper position and location before and during construction. All sleeves must be of sufficient length to pass through entire thickness of walls, partitions, or slabs. Extend sleeves in floor slabs 2 inches above the finished floor. Pack space between the pipe or tubing and the sleeve

firmly with oakum and caulk both ends of the sleeve with elastic cement.

3.1.14 Floor, Wall, and Ceiling Plates

Provide chromium-plated steel or nickel-plated cast iron plates on pipes passing through floors and partitions of finished rooms. Provide painted cast-iron, malleable iron, or steel for other areas.

3.1.15 Flashing for Buildings

Provide flashing in accordance with Section 07 60 00 FLASHING AND SHEET METAL where pipes pass through building roofs and outside walls.

3.1.16 Unions and Flanges

Provide unions and flanges where necessary to permit easy disconnection of piping and apparatus, and as indicated. Provide a union for each connection having a screwed-end valve. Provide unions or flanges not farther apart than 100 feet. Provide unions on piping under 2 inches in diameter, and provide flanges on piping 2 inches and over in diameter. Install dielectric unions or flanges between ferrous and non-ferrous piping, equipment, and fittings; except that bronze valves and fittings may be used without dielectric couplings for ferrous-to-ferrous or non-ferrous to non-ferrous connections.

3.1.17 Painting of Piping and Equipment

Paint piping and equipment in accordance with Section 09 90 00 PAINTS AND COATINGS.

3.1.18 Identification of Piping

Identify piping in accordance with PFI ES 22. Use commercially manufactured piping identification labels. Space identification marking on runs not farther apart than 50 feet. Provide two copies of the piping identification code framed under glass and install where directed.

3.1.19 Warning and Identification Tape

Coordinate installation of utility warning and identification tape with backfill operation. Provide tape above buried lines at a depth of 8 to 12 inches below finish grade.

3.2 CLEANING AND CLEANNESS REQUIREMENTS

Cleaning and cleanliness requirements must conform to ASTM A380/A380M and the following.

3.2.1 Substitution

The word "must" must be substituted for "should" in ASTM A380/A380M.

3.2.2 Prohibited Methods and Processes

The following methods and processes must not be used.

- a. Chemical descaling (acid pickling).
- b. Abrasive blasting and vapor blasting.

- c. Alkaline cleaning.
- d. Emulsion cleaning.
- e. Chelate cleaning.
- f. Acid cleaning.
- g. Passivation.
- h. Corrosion inhibitors must not be used.

3.2.3 Approval of Methods and Procedures

Prepare and submit written cleaning procedures for approval. Perform production cleaning in accordance with approved procedures.

3.2.4 Tools Used on Corrosion-Resistant Alloys

Tools used on corrosion-resistant alloys such as grinding, polishing, filing, deburring, and brushing tools must be visually clean and must not have been used on carbon or low alloy steels, aluminum, lead or materials containing lead or lead components, or other low melting point materials. Wire brushes must be 300 series stainless steel. Unless otherwise approved, each tool must be used on only one type of corrosion-resistant metal.

3.2.5 Cleaning Before Installation

Clean piping, components, and equipment before installation.

3.2.6 Cleaning Requirements

Clean surfaces containing no crevices or inaccessible areas by any of the procedures described herein. Clean surfaces containing crevices by immersion in unused or redistilled acetone, ethanol, or isopropanol only.

3.2.6.1 Vapor Degreasing

Vapor degreasing may be used on surfaces containing no crevices or inaccessible areas and must be accomplished by the following procedures:

- a. Dry all parts entering degreaser.
- b. Load parts onto racks in the condensing zone so that they do not touch each other, and in such a manner to insure complete draining of solvents.
- c. Use perchloroethylene bath. Maintain bath at 250 to 260 degrees F. The bath must contain a neutral inhibitor to prevent acid formation due to hydrolysis. Other types of inhibitors are not permitted.
- d. Change solvent when boiling point of perchloroethylene exceeds 260 degrees F. Dump solvent earlier if cleanliness standards are not attained.
- e. Lower or raise parts in the degreaser at a rate not to exceed 12 inches per minute and immerse in vapor phase. Spray with clean

solvent during immersion time. Keep the spray nozzle at least one foot below the vapor line during spraying. Allow part to remain in vapor until condensation ceases (3 to 5 minutes). Dry parts completely before removing from degreaser.

3.2.6.2 Degreasing by Immersion or Wiping

Degreasing of parts having no inaccessible areas or crevices may be performed by immersion in solvent or by wiping with a clean lintless wiping cloth saturated with the solvent perchloroethylene, unused or redistilled acetone, ethanol, or isopropanol, or Stoddard solvent for preliminary degreasing. Dry in accordance with paragraph entitled "Drying Requirements."

3.2.6.3 Trisodium-Phosphate Detergent Cleaning (Degreasing)

Trisodium-phosphate detergent cleaning may be used on surfaces containing no crevices or inaccessible areas and must be accomplished as follows:

- a. Remove heavy dirt by either scrubbing with a non-shedding bristle brush using a solution of up to one fluid ounce of nonionic detergent per gallon of tap water or immersing the parts in a hot (approximately 160 - 190 degrees F) solution consisting of 7 to 10 ounces of trisodium phosphate and up to one fluid ounce of the nonionic detergent per gallon of tap water for about 20 minutes. Agitate and use brush as necessary.
- b. Rinse parts thoroughly in hot water at a minimum of 120 degree F.
- c. Dry the parts in accordance with paragraph entitled "Drying Requirements."

3.2.6.4 Ultrasonic Cleaning

Cleaning methods using ultrasonic equipment may be used.

3.2.7 Drying Requirements

Accomplish drying by still or forced clean air or inert gas, drying oven, or by evacuation. When using evacuation, exercise care to prevent evacuating-pump lubricant from entering the equipment. Check compressed air used for drying to ensure cleanliness by blowing through a clean, white, cotton filter cloth for about 5 minutes at full drying velocity.

3.2.8 Inspection and Acceptance Criteria for Cleanliness

Conform to ASTM A380/A380M and the following:

3.2.8.1 Cleanness Criteria

All surfaces of piping material, equipment, instruments, and other components which will come in contact with compressed air must be clean to the extent that no contamination is visible to a person with normal visual acuity (natural or corrected) under a lighting level of at least 100 footcandles on the surface being inspected. Cleanness of surface which cannot be visually inspected due to inaccessibility or geometry must be determined by an interpretation of the discoloration or dirt obtained by wiping with a clean, white, wet or dry cloth. Free of contamination must mean free of oil, dirt, metallic flakes, preservatives, paint, and any

other substances which may present a safety hazard or impair the quality of the compressed air.

3.2.8.2 Critical Surfaces

No rust must be allowed on valve seats, orifice plates or other critical surfaces. Thin films of rust are acceptable on other corrosion-resistant material surfaces provided there is no visible thickness or evidence of pitting and the total area involved does not exceed one percent of the total surface area of the component in contact with compressed air.

3.2.8.3 Carbon and Low Alloy Steels

A uniform light rust that can be removed by brushing or wiping is acceptable.

3.2.9 Maintaining Cleanness During Installation

Maintain cleanness of piping, components, and equipment during installation. Dirt and debris producing operations must be performed so that dirt and debris fall away from system openings; otherwise, provide covers over openings to preclude contamination. Cap, plug, cover, or bag openings and pipe ends and secure with tape when they are not required to be open for the performance of work. Metal caps, plugs, and covers must be austenitic stainless steel. Plastic items and tape must be free of substances that can have a harmful effect on stainless steel and other corrosion-resistant metals in the system.

3.2.10 Cleanness Verification Flushes

After installation, check the systems for cleanness by flushing with water. Perform flushing so that the minimum velocity through any part of the system is not less than 3.6 feet per second. Pass flush water through a filter for cleanness evaluation. Filter element must be corrosion-resistant wire cloth with mesh size conforming to ASTM E11, No. 20 (850 micrometers), No. 25 (710 micrometers), or No. 30 (600 micrometers). Filter area must be sufficient to limit pressure drop so that required flushing velocity can be attained.

3.2.10.1 Flush Acceptance Criteria

The system must be flushed until there is no more than slight speckling of particulates on the filter screen. There must be no particles larger than 1/32 by 1/16 inch long. The flush water must show no visual evidence of contamination such as oil particles, discoloration, or iridescent surface film characteristic of oil.

3.2.10.2 Recleaning of Systems

Systems which fail to meet acceptance flush criteria after flushing for more than 4 hours must be recleaned by the Contractor at no additional cost to the Government. Prepare recleaning procedures and submit to the Contracting Officer for approval. Remove instruments, components, and any other items that may be damaged by recleaning. Perform recleaning by flushing with hot water at not less than 140 degrees F.

3.3 CLEANING SILVERBRAZED PIPING

Clean silverbrazed piping to remove residual flux remaining in the system

after fabrication. Use one of the procedures below. The hot flush and hot recirculating flush are preferred. Minimum flow rate through any part of the system in gallons per minute must be 1.5 times the inside diameter of the pipe in inches. For any flushing method used, the system must be full of water so that joints are completely submerged at all times.

3.3.1 Hot Flushing Method

Hot flush the system for one hour using heated fresh water. No part of the system must go below 110 degrees F.

3.3.2 Hot Recirculating Flush Method

Perform hot recirculating flush for one hour. Heat water during flushing so that no part of the system falls below 110 degrees F. After completing the hot recirculating flush, flush the system with cold fresh water for 15 minutes.

3.3.3 Cold Soak Method

Cold soak the system using fresh water at not less than 60 degrees F for 12 hours. Following the 12 hour soak, flush the system with fresh water at not less than 60 degrees F for 4 hours.

3.4 FIELD QUALITY CONTROL

3.4.1 Examinations

3.4.1.1 Welding Examinations

The Contractor must perform visual and nondestructive examinations to detect surface and internal discontinuities in completed welds, and submit a Non-Destructive Examination (NDE) report meeting the requirements specified in ASME B31.1. Visually examine welds. Perform liquid penetrant, or magnetic particle examination as specified in Table II of this section. For systems operating at 1000 psig or higher, all welds must be examined. For high pressure systems operating less than 1000 psig, perform random NDE. When examination and testing indicate defects in a weld joint, the weld must be repaired by a qualified welder. Remove and replace defects as specified in ASME B31.1, unless otherwise specified. Repair defects discovered between weld passes before additional weld material is deposited. Whenever a defect is removed, and repair by welding is not required, blend the affected area into the surrounding surface, eliminating sharp notches, crevices, or corners. After defect removal is complete and before rewelding, examine the area by the same test methods which first revealed the defect to ensure that the defect has been eliminated. After rewelding, reexamine the repaired area by the same test methods originally used for that area. Any indication of a defect must be regarded as a defect unless reevaluation by surface conditioning and NDE shows that no unacceptable defects are present. The use of any foreign material to mask, fill in, seal, or disguise welding defects will not be permitted.

3.4.1.2 Brazing Examinations

The Contractor must perform brazing examinations.

a. Visual Examinations

Visually examine all compressed air systems as follows:

- (1) Check brazed joint fit-up. Diametrical clearances must conform to brazing procedure requirements.
- (2) Check base material of pipe and fitting for conformance to the applicable drawing or specification.
- (3) Check grade of brazing alloy for conformance to the brazing procedure before fit-up or brazing.
- (4) Check completed brazed joint for a complete ring of brazing alloy between the outside surface of the pipe and the face of the fitting, and for a visible fillet.
- (5) Check stainless steel and other susceptible material for evidence of stress cracks. Check inside of joint if possible with borescope or other aids.

b. Nondestructive Examination

For high pressure compressed air systems, any fitting, copper-nickel pipe, or stainless steel tubing which is reused after unsweating a brazed joint must be liquid penetrant examined for cracks. Any crack detected must be cause for rejection of the fitting or pipe. Liquid penetrant examination must be performed by qualified personnel.

c. Repair of Brazed Joints

Defective joints may be repaired. However, no more than two attempts to repair by reheating and additional face feeding of brazing filler metal will be permitted, after which the defective joint must be unsweated, reprepared as a new joint, examined for defects on pipe and fittings, and rebrazed. Perform required NDE.

3.4.2 Testing

3.4.2.1 General Requirements, Testing

Perform testing after cleaning and acceptance of cleanness. Contractor must provide everything required for tests. Tests must be subject to the approval of the Contracting Officer. Calibrate the test pressure gage with a dead weight tester within 15 days before use and certify by initial and date on a sticker applied to dial face. Pressurize each piping system individually and check to assure that there are no cross-connections between different systems prior to hydrostatic and operational tests.

Supervision of Testing

For medium pressure system, an experienced registered professional engineer responsible for safety and employed by the Contractor must be present during testing.

3.4.2.2 Hydrostatic and Leak Tightness Tests

a. Preliminary Preparation

Remove or isolate from the system the compressor, air dryer, filters, instruments, and equipment which would be damaged by water during

hydrostatic tests and reinstall after successful completion of tests.

b. Performance of Hydrostatic Tests

Hydrostatically test piping systems in accordance with ASME B31.1. Vent or flush air from the piping system. Pressurize system for 10 minutes with water at one and one-half times design working pressure, then reduce to design working pressure and check for leaks and weeps.

c. Compressed Air Leak Tightness Test

After satisfactory completion of hydrostatic pressure test, blow systems dry with clean, oil-free compressed air, and test with clean, dry air at design working pressure. Brush joints with soapy water solution to check for leaks. Install a calibrated test pressure gage in piping system to observe any loss in pressure. Maintain required test pressure for a sufficient length of time to enable an inspection of joints and connections.

d. Compressed Air Pressure Test For High Pressure Systems

For high pressure systems, compressed air at system design pressure must then stand in a system to equalize temperature. Pressure drop, corrected for temperature change, must not be more than one percent in 24 hours for a test pressure 1000 psig and above, and not over 5 percent in 6 hours for test pressures from 400 to 1000 psig. Use formula below to correct pressure for temperature change.

$PF + 14.7 = (PI + 14.7)(TF + 460)/(TI + 460)$
Where PF = Final Pressure, (psig)
Where PI = Initial Pressure, (psig)
Where TF = Final Temperature, (degrees F)
Where TI = Initial Temperature (degrees F)

3.4.2.3 Operational Tests

Test equipment as in service to determine compliance with contract requirements and warranty. During the tests, test equipment under every condition of operation. Test safety controls to demonstrate performance of their required function. Completely test system for compliance with specifications.

3.5 INSTRUCTION TO GOVERNMENT PERSONNEL

Provide 2 man-days of instruction to 2 Government personnel in accordance with Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND METHODS for each type of compressor and compressed air dryer in the project.

TABLE II						
HP Piping (400 psig and Higher) Inspection Requirements <u>1/</u>						
Required Nondestructive Examination						
<u>Welded Joint type and pipe size, inches</u>	<u>VISUAL EXAMINATION</u>		<u>T/PT TEST</u>		<u>RADIOGRAPHY</u>	
	<u>Root Layer</u>	<u>Completed Weld</u>	<u>Root Layer</u>	<u>Completed Weld</u>	<u>Completed Weld</u>	<u>Extent Of</u>
Butt 4 and greater	X _{2/}	X	X _{2/}	X _{3/}	X	360 degrees
Butt 2-1/2 to 3-1/2 incl.	X _{2/}	X	X _{2/}	X _{3/}	X _{4/5/}	At least 60 degrees
Butt less than 2-1/2	X _{2/}	X	X _{2/}	X _{3/}	X _{4/5/6/}	At least 60 degrees
All socket and fillets	X _{2/}	X	X _{2/}	X	--	--

Legend: X - Indicates that test is required.

MT Magnetic Particle Inspection

PT Liquid Penetrant Inspection

RT Radiographic Examination

NOTES:

1/ Where new welds in piping intersects existing or older welds, the latter welds must be inspected for a distance of 6 inches or a distance equal to 50 percent of the pipe size diameter, whichever is less, as measured from points of intersection. The existing or older weld and adjacent base material must be free from cracks. Where non-intersecting adjacent existing welds are inadvertently radiographed, only cracks must be cause for rejection.

2/ MT/PT inspect the first or root pass of welds and when accessible, the reverse or back-chipped ground, gouged or machined side prior to depositing metal on the reverse side. Visual examination at 5X magnification may be substituted for MT/PT inspection. Linear discontinuities must be unacceptable. Use 5X inspection where crevices cannot be cleaned thoroughly.

3/ MT/PT test must be performed only when post-weld heat treatment is required and when specified on drawing. The test must be conducted after heat treatment and must include 360 degrees of circumferential weld surface and adjacent base material. Where 360 degrees RT is performed after heat treatment, MT/PT is not required, except where specified on drawing.

4/ RT of welds on piping in the horizontal fixed position must represent a sector which was welded in the vertical or overhead position.

5/ In lieu of 60 degree RT, PT or MT may be performed on the inside of a joint where weld is within 2 1/2 nominal pipe diameters from the open end is back welded, has backing ring removed or used consumable insert.

6/ RT is required where the working pressure exceeds 575 psig. For working pressure 575 psig and below, inspection may be performed in lieu of RT.

-- End of Section --

SECTION 23 03 00.00 20

BASIC MECHANICAL MATERIALS AND METHODS
08/10, CHG 3: 08/18

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM B117 (2019) Standard Practice for Operating Salt Spray (Fog) Apparatus

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C2 (2023) National Electrical Safety Code

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA MG 1 (2021) Motors and Generators

NEMA MG 10 (2017) Energy Management Guide for Selection and Use of Fixed Frequency Medium AC Squirrel-Cage Polyphase Induction Motors

NEMA MG 11 (1977; R 2012) Energy Management Guide for Selection and Use of Single Phase Motors

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code

1.2 RELATED REQUIREMENTS

This section applies to all sections of Divisions: 21, FIRE SUPPRESSION; 22, PLUMBING; and 23, HEATING, VENTILATING, AND AIR CONDITIONING of this project specification, unless specified otherwise in the individual section.

1.3 QUALITY ASSURANCE

1.3.1 Material and Equipment Qualifications

Provide materials and equipment that are standard products of manufacturers regularly engaged in the manufacture of such products, which are of a similar material, design and workmanship. Standard products must have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use must include applications of equipment and materials under similar circumstances and of similar size. The product must have been for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2 year period.

1.3.2 Alternative Qualifications

Products having less than a two-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturer's factory or laboratory tests, can be shown.

1.3.3 Service Support

The equipment items must be supported by service organizations. Submit a certified list of qualified permanent service organizations for support of the equipment which includes their addresses and qualifications. These service organizations must be reasonably convenient to the equipment installation and able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

1.3.4 Manufacturer's Nameplate

For each item of equipment, provide a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

1.3.5 Modification of References

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "must" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction", or words of similar meaning, to mean the Contracting Officer.

1.3.5.1 Definitions

For the International Code Council (ICC) Codes referenced in the contract documents, advisory provisions must be considered mandatory, the word "should" is interpreted as "must." Reference to the "code official" must be interpreted to mean the "Contracting Officer." For Navy owned property, references to the "owner" must be interpreted to mean the "Contracting Officer." For leased facilities, references to the "owner" must be interpreted to mean the "lessor." References to the "permit holder" must be interpreted to mean the "Contractor."

1.3.5.2 Administrative Interpretations

For ICC Codes referenced in the contract documents, the provisions of Chapter 1, "Administrator," do not apply. These administrative requirements are covered by the applicable Federal Acquisition Regulations (FAR) included in this contract and by the authority granted to the Officer in Charge of Construction to administer the construction of this project. References in the ICC Codes to sections of Chapter 1, must be applied appropriately by the Contracting Officer as authorized by his administrative cognizance and the FAR.

1.4 DELIVERY, STORAGE, AND HANDLING

Handle, store, and protect equipment and materials to prevent damage before and during installation in accordance with the manufacturer's recommendations, and as approved by the Contracting Officer. Replace

damaged or defective items.

1.5 ELECTRICAL REQUIREMENTS

Furnish motors, controllers, disconnects and contactors with their respective pieces of equipment. Motors, controllers, disconnects and contactors must conform to and have electrical connections provided under Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Furnish internal wiring for components of packaged equipment as an integral part of the equipment. Extended voltage range motors will not be permitted. Controllers and contactors shall have a maximum of 120 volt control circuits, and must have auxiliary contacts for use with the controls furnished. When motors and equipment furnished are larger than sizes indicated, the cost of additional electrical service and related work must be included under the section that specified that motor or equipment. Power wiring and conduit for field installed equipment must be provided under and conform to the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

1.6 ELECTRICAL INSTALLATION REQUIREMENTS

Electrical installations must conform to IEEE C2, NFPA 70, and requirements specified herein.

1.6.1 New Work

Provide electrical components of mechanical equipment, such as motors, motor starters (except starters/controllers which are indicated as part of a motor control center), control or push-button stations, float or pressure switches, solenoid valves, integral disconnects, and other devices functioning to control mechanical equipment, as well as control wiring and conduit for circuits rated 100 volts or less, to conform with the requirements of the section covering the mechanical equipment. Extended voltage range motors are not to be permitted. The interconnecting power wiring and conduit, control wiring rated 120 volts (nominal) and conduit, the motor control equipment forming a part of motor control centers, and the electrical power circuits must be provided under Division 26, except internal wiring for components of package equipment must be provided as an integral part of the equipment. When motors and equipment furnished are larger than sizes indicated, provide any required changes to the electrical service as may be necessary and related work as a part of the work for the section specifying that motor or equipment.

1.6.2 Modifications to Existing Systems

Where existing mechanical systems and motor-operated equipment require modifications, provide electrical components under Division 26.

1.6.3 High Efficiency Motors

1.6.3.1 High Efficiency Single-Phase Motors

Unless otherwise specified, single-phase fractional-horsepower alternating-current motors must be high efficiency types corresponding to the applications listed in NEMA MG 11.

1.6.3.2 High Efficiency Polyphase Motors

Unless otherwise specified, polyphase motors must be selected based on high efficiency characteristics relative to the applications as listed in

NEMA MG 10. Additionally, polyphase squirrel-cage medium induction motors with continuous ratings must meet or exceed energy efficient ratings in accordance with Table 12-6C of NEMA MG 1.

1.6.4 Three-Phase Motor Protection

Provide controllers for motors rated one 1 horsepower and larger with electronic phase-voltage monitors designed to protect motors from phase-loss, undervoltage, and overvoltage. Provide protection for motors from immediate restart by a time adjustable restart relay.

1.7 INSTRUCTION TO GOVERNMENT PERSONNEL

When specified in other sections, furnish the services of competent instructors to give full instruction to the designated Government personnel in the adjustment, operation, and maintenance, including pertinent safety requirements, of the specified equipment or system. Instructors must be thoroughly familiar with all parts of the installation and must be trained in operating theory as well as practical operation and maintenance work.

Instruction must be given during the first regular work week after the equipment or system has been accepted and turned over to the Government for regular operation. The number of man-days (8 hours per day) of instruction furnished must be as specified in the individual section. When more than 4 man-days of instruction are specified, use approximately half of the time for classroom instruction. Use other time for instruction with the equipment or system.

When significant changes or modifications in the equipment or system are made under the terms of the contract, provide additional instruction to acquaint the operating personnel with the changes or modifications.

1.8 ACCESSIBILITY

Install all work so that parts requiring periodic inspection, operation, maintenance, and repair are readily accessible. Install concealed valves, expansion joints, controls, dampers, and equipment requiring access, in locations freely accessible through access doors.

PART 2 PRODUCTS

Not Used

PART 3 EXECUTION

3.1 PAINTING OF NEW EQUIPMENT

New equipment painting must be factory applied or shop applied, and must be as specified herein, and provided under each individual section.

3.1.1 Factory Painting Systems

Manufacturer's standard factory painting systems may be provided subject to certification that the factory painting system applied will withstand 125 hours in a salt-spray fog test, except that equipment located outdoors must withstand 500 hours in a salt-spray fog test. Salt-spray fog test must be in accordance with ASTM B117, and for that test the acceptance criteria must be as follows: immediately after completion of the test,

the paint must show no signs of blistering, wrinkling, or cracking, and no loss of adhesion; and the specimen must show no signs of rust creepage beyond 0.125 inch on either side of the scratch mark.

The film thickness of the factory painting system applied on the equipment must not be less than the film thickness used on the test specimen. If manufacturer's standard factory painting system is being proposed for use on surfaces subject to temperatures above 120 degrees F, the factory painting system must be designed for the temperature service.

3.1.2 Shop Painting Systems for Metal Surfaces

Clean, pretreat, prime and paint metal surfaces; except aluminum surfaces need not be painted. Apply coatings to clean dry surfaces. Clean the surfaces to remove dust, dirt, rust, oil and grease by wire brushing and solvent degreasing prior to application of paint, except metal surfaces subject to temperatures in excess of 120 degrees F must be cleaned to bare metal.

Where more than one coat of paint is specified, apply the second coat after the preceding coat is thoroughly dry. Lightly sand damaged painting and retouch before applying the succeeding coat. Color of finish coat must be aluminum or light gray.

- a. Temperatures Less Than 120 Degrees F: Immediately after cleaning, the metal surfaces subject to temperatures less than 120 degrees F must receive one coat of pretreatment primer applied to a minimum dry film thickness of 0.3 mil, one coat of primer applied to a minimum dry film thickness of 1 mil; and two coats of enamel applied to a minimum dry film thickness of 1 mil per coat.
- b. Temperatures Between 120 and 400 Degrees F: Metal surfaces subject to temperatures between 120 and 400 degrees F must receive two coats of 400 degrees F heat-resisting enamel applied to a total minimum thickness of 2 mils.
- c. Temperatures Greater Than 400 Degrees F: Metal surfaces subject to temperatures greater than 400 degrees F must receive two coats of 600 degrees F heat-resisting paint applied to a total minimum dry film thickness of 2 mils.

-- End of Section --

SECTION 23 05 15

COMMON PIPING FOR HVAC
05/22, CHG 1: 02/24

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 325 (2017) Steel Construction Manual

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME A112.18.1/CSA B125.1 (2018) Plumbing Supply Fittings

ASME A112.19.2/CSA B45.1 (2018; ERTA 2018) Standard for Vitreous China Plumbing Fixtures and Hydraulic Requirements for Water Closets and Urinals

ASME B1.20.7 (1991; R 2013) Standard for Hose Coupling Screw Threads (Inch)

ASME B16.1 (2020) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250

ASME B16.3 (2021) Malleable Iron Threaded Fittings, Classes 150 and 300

ASME B16.5 (2020) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard

ASME B16.9 (2018) Factory-Made Wrought Buttwelding Fittings

ASME B16.22 (2021) Wrought Copper and Copper Alloy Solder Joint Pressure Fittings

ASME B16.25 (2022) Buttwelding Ends

ASME B16.34 (2021) Valves - Flanged, Threaded and Welding End

ASME B16.39 (2020) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300

ASME B31.3 (2022; Errata 2023) Process Piping

ASME B40.100 (2022) Pressure Gauges and Gauge Attachments

ASME BPVC SEC IX (2017; Errata 2018) BPVC Section

IX-Welding, Brazing and Fusing
Qualifications

ASME BPVC SEC VIII D1 (2019) BPVC Section VIII-Rules for
Construction of Pressure Vessels Division 1

AMERICAN WELDING SOCIETY (AWS)

AWS A5.8/A5.8M (2019) Specification for Filler Metals for
Brazing and Braze Welding

AWS WHB-2.9 (2004) Welding Handbook; Volume 2, Welding
Processes, Part 1

ASTM INTERNATIONAL (ASTM)

ASTM A6/A6M (2017) Standard Specification for General
Requirements for Rolled Structural Steel
Bars, Plates, Shapes, and Sheet Piling

ASTM A53/A53M (2022) Standard Specification for Pipe,
Steel, Black and Hot-Dipped, Zinc-Coated,
Welded and Seamless

ASTM A126 (2004; R 2023) Standard Specification for
Gray Iron Castings for Valves, Flanges,
and Pipe Fittings

ASTM A197/A197M (2020; R 2023; E 2023) Standard
Specification for Cupola Malleable Iron

ASTM A234/A234M (2023a) Standard Specification for Piping
Fittings of Wrought Carbon Steel and Alloy
Steel for Moderate and High Temperature
Service

ASTM A307 (2021) Standard Specification for Carbon
Steel Bolts, Studs, and Threaded Rod 60
000 PSI Tensile Strength

ASTM A480/A480M (2023b) Standard Specification for General
Requirements for Flat-Rolled Stainless and
Heat-Resisting Steel Plate, Sheet, and
Strip

ASTM A563 (2021; E 2022a) Standard Specification for
Carbon and Alloy Steel Nuts

ASTM A888 (2023) Standard Specification for Hubless
Cast Iron Soil Pipe and Fittings for
Sanitary and Storm Drain, Waste, and Vent
Piping Applications

ASTM B62 (2017) Standard Specification for
Composition Bronze or Ounce Metal Castings

ASTM B88 (2022) Standard Specification for Seamless
Copper Water Tube

ASTM B117	(2019) Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM B370	(2022) Standard Specification for Copper Sheet and Strip for Building Construction
ASTM B749	(2020) Standard Specification for Lead and Lead Alloy Strip, Sheet and Plate Products
ASTM C67/C67M	(2023a) Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile
ASTM C109/C109M	(2023) Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens)
ASTM C404	(2024) Standard Specification for Aggregates for Masonry Grout
ASTM C476	(2023) Standard Specification for Grout for Masonry
ASTM C553	(2013; R 2019) Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
ASTM C920	(2018) Standard Specification for Elastomeric Joint Sealants
ASTM D2308	(2007; R 2013) Standard Specification for Thermoplastic Polyethylene Jacket for Electrical Wire and Cable
ASTM E1	(2014) Standard Specification for ASTM Liquid-in-Glass Thermometers
ASTM E814	(2023a) Standard Test Method for Fire Tests of Penetration Firestop Systems
ASTM F104	(2011; R 2020) Standard Classification System for Nonmetallic Gasket Materials
ASTM F2389	(2023) Standard Specification for Pressure-rated Polypropylene (PP) Piping Systems

CAST IRON SOIL PIPE INSTITUTE (CISPI)

CISPI 310	(2012) Coupling for Use in Connection with Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications
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FLUID SEALING ASSOCIATION (FSA)

FSA-0017	(1995e6) Standard for Non-Metallic Expansion Joints and Flexible Pipe Connectors Technical Handbook
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INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 515 (2017) Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-58 (2018) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation

MSS SP-67 (2022) Butterfly Valves

MSS SP-70 (2011) Gray Iron Gate Valves, Flanged and Threaded Ends

MSS SP-72 (2010a) Ball Valves with Flanged or Butt-Welding Ends for General Service

MSS SP-80 (2019) Bronze Gate, Globe, Angle and Check Valves

MSS SP-110 (2010) Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends

MSS SP-125 (2010) Gray Iron and Ductile Iron In-Line, Spring-Loaded, Center-Guided Check Valves

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-C-18480 (1982; Rev B; Notice 2 2009; Notice 3 2022) Coating Compound, Bituminous, Solvent, Coal-Tar Base

MIL-DTL-17813 (2009; Rev H; Supp 1 2009; Notice 1 2013; Notice 2 2018; Notice 3 2023) Expansion Joints, Pipe, Metallic Bellows, General Specification for

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

CID A-A-1922 (Rev A; Notice 1; Notice 2; Notice 3; Notice 4) Shield, Expansion (Caulking Anchors, Single Lead)

CID A-A-1923 (Rev A; Notice 1; Notice 2; Notice 3; Notice 4) Shield, Expansion (Lag, Machine and Externally Threaded Wedge Bolt Anchors)

CID A-A-1924 (Rev A; Notice 3) Shield, Expansion (Self Drilling Tubular Expansion Shell Bolt Anchors)

CID A-A-1925 (Rev A; Notice 1; Notice 2; Notice 3;

Notice 4) Shield Expansion (Nail Anchors)

CID A-A-55614

(Basic; Notice 2) Shield, Expansion
(Non-Drilling Expansion Anchors)

CID A-A-55615

(Basic; Notice 1; Notice 2; Notice 3;
Notice 4) Shield, Expansion (Wood Screw
and Lag Bolt Self-Threading Anchors)

UNDERWRITERS LABORATORIES (UL)

UL 1479

(2015; Reprint May 2021) Fire Tests of
Through-Penetration Firestops

1.2 GENERAL REQUIREMENTS

- a. Section 23 30 00 HVAC AIR DISTRIBUTION applies to work specified in this section
- d. Submit Records of Existing Conditions consisting of the results of Contractor's survey of work area conditions and features of existing structures and facilities within and adjacent to the jobsite. Commencement of work constitutes acceptance of the existing conditions.
- e. Include with Equipment Foundation Data for piping systems all plan dimensions of foundations and relative elevations, equipment weight and operating loads, horizontal and vertical loads, horizontal and vertical clearances for installation, and size and location of anchor bolts.
- f. Submit Fabrication Drawings for pipes, valves and specialties consisting of fabrication and assembly details to be performed in the factory.
- g. Submit Material, Equipment, and Fixture Lists for pipes, valves and specialties including manufacturer's style or catalog numbers, specification and drawing reference numbers, warranty information, and fabrication site information. Provide a complete list of construction equipment to be used.
- h. Submit Manufacturer's Standard Color Charts for pipes, valves and specialties showing the manufacturer's recommended color and finish selections.
- i. Include with Listing of Product Installations for piping systems identification of at least 5 units, similar to those proposed for use, that have been in successful service for a minimum period of 5 years. Include in the list purchaser, address of installation, service organization, and date of installation.
- j. Submit Record Drawings for pipes, valves and accessories providing current factual information including deviations and amendments to the drawings, and concealed and visible changes in the work.
- k. Submit Connection Diagrams for pipes, valves and specialties indicating the relations and connections of devices and apparatus by showing the general physical layout of all controls, the interconnection of one system (or portion of system) with another, and internal tubing, wiring, and other devices.

1. Submit Coordination Drawings for pipes, valves and specialties showing coordination of work between different trades and with the structural and architectural elements of work. Detail all drawings sufficiently to show overall dimensions of related items, clearances, and relative locations of work in allotted spaces. Indicate on drawings where conflicts or clearance problems exist between various trades.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material, Equipment, and Fixture Lists; G

SD-02 Shop Drawings

Record Drawings; G

Connection Diagrams; G

Coordination Drawings; G

Fabrication Drawings; G

Installation Drawings; G

SD-03 Product Data

Pipe and Fittings; G

Piping Specialties; G

Valves; G

Miscellaneous Materials; G

Supporting Elements; G

Equipment Foundation Data; G

SD-04 Samples

Manufacturer's Standard Color Charts; G

SD-05 Design Data

Pipe and Fittings; G

Piping Specialties; G

Valves; G

SD-06 Test Reports

Hydrostatic Tests; G

Air Tests; G

Valve-Operating Tests; G

Drainage Tests; G

Pneumatic Tests; G

Non-Destructive Electric Tests; G

System Operation Tests; G

SD-07 Certificates

Record of Satisfactory Field Operation; G

List of Qualified Permanent Service Organizations; G

Listing of Product Installations; G

Records of Existing Conditions; G

Surface Resistance; G

Shear and Tensile Strengths; G

Temperature Ratings; G

Bending Tests; G

Flattening Tests; G

Transverse Guided Weld Bend Tests; G

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G

1.4 QUALITY ASSURANCE

1.4.1 Material and Equipment Qualifications

Provide materials and equipment that are standard products of manufacturers regularly engaged in the manufacture of such products, which are of a similar material, design and workmanship. Provide standard products in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use includes applications of equipment and materials under similar circumstances and of similar size. Ensure the product has been for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2 year period.

1.4.2 Alternative Qualifications

Products having less than a two-year field service record are acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturer's factory or laboratory tests, can be shown.

1.4.3 Service Support

Ensure the equipment items are supported by service organizations. Submit a certified list of qualified permanent service organizations for support of the equipment which includes their addresses and qualifications. Select service organizations that are reasonably convenient to the equipment installation and able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

1.4.4 Manufacturer's Nameplate

Provide a nameplate on each item of equipment bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent is not acceptable.

1.4.5 Modification of References

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer.

1.4.5.1 Definitions

For the International Code Council (ICC) Codes referenced in the contract documents, advisory provisions are considered mandatory, the word "should" is interpreted as "shall." Reference to the "code official" is interpreted to mean the "Contracting Officer." For Navy owned property, interpret references to the "owner" to mean the "Contracting Officer." For leased facilities, references to the "owner" is interpreted to mean the "lessor." References to the "permit holder" are interpreted to mean the "Contractor."

1.4.5.2 Administrative Interpretations

For ICC Codes referenced in the contract documents, the provisions of Chapter 1, "Administrator," do not apply. These administrative requirements are covered by the applicable Federal Acquisition Regulations (FAR) included in this contract and by the authority granted to the Officer in Charge of Construction to administer the construction of this project. References in the ICC Codes to sections of Chapter 1, are applied as appropriate by the Contracting Officer and as authorized by his administrative cognizance and the FAR.

1.5 DELIVERY, STORAGE, AND HANDLING

Handle, store, and protect equipment and materials to prevent damage before and during installation in accordance with the manufacturer's recommendations, and as approved by the Contracting Officer. Replace damaged or defective items.

1.6 ELECTRICAL REQUIREMENTS

Furnish motors, controllers, disconnects and contactors with their respective pieces of equipment. Ensure motors, controllers, disconnects

and contactors conform to and have electrical connections provided under Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Furnish internal wiring for components of packaged equipment as an integral part of the equipment. Extended voltage range motors is not permitted. Provide controllers and contactors with a maximum of 120 volt control circuits, and auxiliary contacts for use with the controls furnished. When motors and equipment furnished are larger than sizes indicated, include the cost of additional electrical service and related work under the section that specified that motor or equipment. Provide power wiring and conduit for field installed equipment under and conform to the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

1.7 INSTRUCTION TO GOVERNMENT PERSONNEL

When specified in other sections, furnish the services of competent instructors to give full instruction to the designated Government personnel in the adjustment, operation, and maintenance, including pertinent safety requirements, of the specified equipment or system. Provide instructors thoroughly familiar with all parts of the installation and trained in operating theory as well as practical operation and maintenance work.

Give instruction during the first regular work week after the equipment or system has been accepted and turned over to the Government for regular operation. The number of man-days (8 hours per day) of instruction furnished is as specified in the individual section. When more than four man-days of instruction are specified, use approximately half of the time for classroom instruction. Use other time for instruction with the equipment or system.

When significant changes or modifications in the equipment or system are made under the terms of the contract, provide additional instruction to acquaint the operating personnel with the changes or modifications.

1.8 ACCESSIBILITY

Install all work so that parts requiring periodic inspection, operation, maintenance, and repair are readily accessible. Install concealed valves, expansion joints, controls, dampers, and equipment requiring access, in locations freely accessible through access doors.

PART 2 PRODUCTS

2.1 ELECTRICAL HEAT TRACING

Provide heat trace systems for pipes, valves, and fittings that are in accordance with IEEE 515 and be UL listed. System include all necessary components, including heaters and controls to prevent freezing.

Provide self-regulating heaters consisting of two 16 AWG tinned-copper bus wires embedded in parallel in a self-regulating polymer core that varies its power output to respond to temperature along its length. Ensure heater is able to be crossed over itself without overheating. Obtain approval before used directly on plastic pipe. Cover heater with a radiation cross-linked modified polyolefin dielectric jacket in accordance with ASTM D2308.

Provide heater with self-regulating factor of at least 90 percent, in

order to provide energy conservation and to prevent overheating.

Operate heater on line voltages of 120 volts without the use of transformers.

Size Heater according to the following table:

Pipe Size

(Inch, Diameter)	Minus 10 degrees F	Minus 20 degrees F
3 inches or less	5 watts per foot (wpf)	5 wpf
4 inch	5 wpf	8 wpf
6 inch	8 wpf	8 wpf
8 inch	2 strips/5 wpf	2 strips/8 wpf
12 inch	2 strips/8 wpf	2 strips/8 wpf

Control systems by an ambient sensing thermostat set at 40 degrees F either directly or through an appropriate contactor.

2.2 PIPE AND FITTINGS

Submit equipment and performance data for pipe and fittings consisting of corrosion resistance, life expectancy, gage tolerances, and grade line analysis. Submit design analysis and calculations consisting of surface resistance, rates of flow, head losses, inlet and outlet design, required radius of bend, and pressure calculations. Also include in data pipe size, shape, and dimensions, as well as temperature ratings, vibration and thrust limitations minimum burst pressures, shut-off and non-shock pressures and weld characteristics.

2.2.1 Type BCS, Black Carbon Steel

Ensure pipe 1/8 through 12 inches is Schedule 40 black carbon steel, conforming to ASTM A53/A53M.

Ensure pipe 1/8 through 10 inches is Schedule 40 seamless or electric-resistance welded black carbon steel, conforming to ASTM A53/A53M, Type E, Grade B (electric-resistance welded) . Grade A should be used for permissible field bending, in both cases.

Ensure pipe 12 through 24 inches is 0.375-inch wall seamless black carbon steel, conforming to ASTM A53/A53M, Type S (seamless).

Ensure fittings 2 inches and under are 150-pounds per square inch, gage (psig) working steam pressure (wsp) banded black malleable iron screwed, conforming to ASTM A197/A197M and ASME B16.3.

Ensure unions 2 inches and under are 250 pounds per square inch, wsp female, screwed, black malleable iron with brass-to-iron seat, and ground joint, conforming to ASME B16.39.

Ensure fittings 2-1/2 inches and over are Steel butt weld, conforming to

ASTM A234/A234M and ASME B16.9 to match pipe wall thickness.

Ensure flanges 2-1/2 inches and over are 150-pound forged-steel conforming to ASME B16.5, welding neck to match pipe wall thickness.

2.2.2 Type CISP-DWV, Cast-Iron Drain, Waste and Vent

Provide soil pipe drain, waste, and vent hubless cast iron pipe and fittings, conforming to ASTM A888. Joints shall be heavyweight no-hub couplings with stainless steel clamps, conforming to CISPI 310.

2.2.3 Type CPR, Copper

2.2.3.1 Type CPR-A, Copper Above Ground

Ensure tubing 2 inches and under is seamless copper tubing, conforming to ASTM B88, Type L (hard-drawn for all horizontal and all exposed vertical lines, annealed for concealed vertical lines).

Ensure fittings 2 inches and under are 150-psig wsp wrought-copper solder joint fittings conforming to ASME B16.22.

Ensure unions 2 inches and under are 150-psig wsp wrought-copper solder joint, conforming to ASME B16.22.

Provide brazing rod with Classification BCuP-5, conforming to AWS A5.8/A5.8M.

2.3 PIPING SPECIALTIES

Submit equipment and performance data for piping specialties consisting of corrosion resistance, life expectancy, gage tolerances, and grade line analysis. Submit design analysis and calculations consisting of surface resistance, rates of flow, head losses, inlet and outlet design, required radius of bend, and pressure calculations. Also include in data pipe size, shape, and dimensions, as well as temperature ratings, vibration and thrust limitations minimum burst pressures, shut-off and non-shock pressures and weld characteristics.

2.3.1 Air Separator

Air separated from converter discharge water is ejected by a reduced-velocity device vented to the compression tank.

Provide a commercially constructed separator, designed and certified to separate not less than 80 percent of entrained air on the first passage of water and not less than 80 percent of residual on each successive pass. Provide shop drawings detailing all piping connections proposed for this work.

2.3.2 Air Vents

Provide manual air vents using 3/8-inch globe valves.

Provide automatic air vents on pumps, mains, and where indicated using ball-float construction. Ensure the vent inlet is not less than 3/4-inch ips and the outlet not less than 1/4-inch ips. Orifice size is 1/8 inch. Provide corrosion-resistant steel trim conforming to ASTM A480/A480M. Fit

vent with try-cock. Ensure vent discharges air at any pressure up to 150 psi. Ensure outlet is copper tube routed.

2.3.3 Compression Tank

Provide compression tank designed, fabricated, tested, and stamped for a working pressure of not less than 125 psi in accordance with ASME BPVC SEC VIII D1. Ensure tank is hot-dip galvanized after fabrication to produce not less than 1.5 ounces of zinc coating per square foot of single-side surface.

Tank accessories include red-lined gage-glass complete with glass protectors and shutoff valves, air charger and drainer, and manual vent.

2.3.4 Dielectric Connections

Electrically isolate dissimilar pipe metals from each other by couplings, unions, or flanges commercially manufactured for that purpose and rated for the service pressure and temperature.

2.3.5 Expansion Vibration Isolation Joints

Construct single or multiple arch-flanged expansion vibration isolation joints of steel-ring reinforced chloroprene-impregnated cloth materials. Design joint to absorb the movement of the pipe sections in which installed with no detrimental effect on the pipe or connected equipment. Back flanges with ferrous-metal backing rings. Provide control rod assemblies to restrict joint movement. Coat all nonmetallic exterior surfaces of the joint with chlorosulphonated polyethylene. Provide grommets in limit bolt hole to absorb noise transmitted through the bolts.

Ensure joints are suitable for continuous-duty working temperature of at least 250 degrees F.

Fill arches with soft chloroprene.

Ensure joint, single-arch, movement limitations and size-related, pressure characteristics conform to FSA-0017.

2.3.6 Flexible Pipe

Construct flexible pipe vibration and pipe-noise eliminators of wire-reinforced, rubber-impregnated cloth and cord materials and be flanged. Back the flanges with ferrous-metal backing rings. Ensure service pressure-rating is a minimum 1.5 times actual service, with surge pressure at 180 degrees F.

Construct flexible pipe vibration and pipe noise eliminators of wire-reinforced chloroprene-impregnated cloth and cord materials. Ensure the pipe is flanged. Provide all flanges backed with ferrous-metal backing rings. Coat nonmetallic exterior surfaces of the flexible pipe with an acid- and oxidation-resistant chlorosulphonated polyethylene. Rate the flexible pipe for continuous duty at 130 psi and 250 degrees F.

Ensure unit pipe lengths, face-to-face, are not less than the following:

<u>INSIDE DIAMETER</u>	<u>UNIT PIPE LENGTH</u>
To 2-1/2 inches, inclusive	12 inches

<u>INSIDE DIAMETER</u>	<u>UNIT PIPE LENGTH</u>
3 to 4 inches, inclusive	18 inches
5 to 12 inches, inclusive	24 inches
To 3 inches, inclusive	18 inches
4 to 10 inches, inclusive	24 inches
12 inches and larger	36 inches

2.3.7 Flexible Metallic Pipe

Ensure flexible pipe is the bellows-type with wire braid cover and designed, constructed, and rated in accordance with the applicable requirements of ASME B31.3.

Minimum working pressure rating is 50 psi at 300 degrees F.

Ensure minimum burst pressure is four times working pressure at 300 degrees F. Bellows material is AISI Type 316L corrosion-resistant steel. Ensure braid is AISI 300 series corrosion-resistant steel wire.

2.3.8 Metallic Expansion Joints

Provide metallic-bellows expansion joints conforming to MIL-DTL-17813.

Design and construct joints to absorb all of the movements of the pipe sections in which installed, with no detrimental effect on pipe or supporting structure.

Rate, design, and construct joints for pressures to 125 psig and temperatures to 500 degrees F.

Ensure joints have a designed bursting strength in excess of four times their rated pressure.

Ensure joints are capable of withstanding a hydrostatic test of 1.5 times their rated pressure while held at their uncompressed length without leakage or distortion that may adversely affect their life cycle.

Ensure life expectancy is not less than 10,000 cycles.

Ensure movement capability of each joint exceeds calculated movement of piping by 100 percent.

Provide bellows and internal sleeve material of AISI Type 304, 304L, or 321 corrosion-resistant steel.

End connections require no field preparation other than cleaning.

Butt weld end preparation of expansion joints conform to the same codes and standards requirements as applicable to the piping system materials at the indicated joint location.

Provide joints, 2-1/2 inches and smaller, with internal guides and limit stops.

Provide joints, 3 inches and larger, with removable external covers, internal sleeves, and purging connection. Size sleeves to accommodate lateral clearance required, with minimum reduction of flow area, and with oversized bellows where necessary. When a sleeve requires a gasket as part of a locking arrangement, provide the gasket used by the manufacturer. Joints without purging connection may be provided; however, remove these from the line prior to, or not installed until, cleaning operations are complete.

Provide the cylindrical end portion of the reinforced bellows element with a thrust sleeve of sufficient thickness to bring that portion within applicable code-allowable stress. Provide 360 degrees support for the element and end-reinforcing ring with the sleeve.

Ensure each expansion joint has adjustable clamps or yokes provided at quarter points, straddling the bellows. Overall joint length is set by the manufacturer to maintain joints in manufacturer's recommended position during installation.

Permanently and legibly mark each joint with the manufacturer's name or trademark and serial number; the size, series, or catalog number; bellows material; and directional-flow arrow.

2.3.9 Hose Faucets

Construct hose faucets with 1/2 inch male inlet threads, hexagon shoulder, and 3/4 inch hose connection, conforming to ASME A112.18.1/CSA B125.1. Ensure hose-coupling screw threads conform to ASME B1.20.7.

Provide vandal proof, atmospheric-type vacuum breaker on the discharge of all potable water lines.

2.3.10 Pressure Gages

Ensure pressure gages conform to ASME B40.100 and to requirements specified herein. Pressure-gage size is 3-1/2 inches nominal diameter. Ensure case is corrosion-resistant steel, conforming to any of the AISI 300 series of ASTM A6/A6M, with an ASM No. 4 standard commercial polish or better. Equip gages with adjustable red marking pointer and damper-screw adjustment in inlet connection. Align service-pressure reading at midpoint of gage range. Ensure all gages are Grade B or better and be equipped with gage isolators.

2.3.11 Sight-Flow Indicators

Construct sight-flow indicators for pressure service on 3-inch ips and smaller of bronze with specially treated single- or double-glass sight windows and have a bronze, nylon, or tetrafluoroethylene rotating flow indicator mounted on an AISI Type 304 corrosion-resistant steel shaft. Body may have screwed or flanged end. Provide pressure- and temperature-rated assembly for the applied service. Flapper flow-type indicators are not acceptable.

2.3.12 Sleeve Couplings

Sleeve couplings for plain-end pipe consist of one steel middle ring, two steel followers, two chloroprene or Buna-N elastomer gaskets, and the necessary steel bolts and nuts.

2.3.13 Thermometers

Ensure thermometers conform to ASTM E1, except for being filled with a red organic liquid. Provide an industrial pattern armored glass thermometer, (well-threaded and seal-welded). Ensure thermometers installed 6 feet or higher above the floor have an adjustable angle body. Ensure scale is not less than 7 inches long and the case face is manufactured from manufacturer's standard polished aluminum or AISI 300 series polished corrosion-resistant steel. Thermometer range is . Provide thermometers with nonferrous separable wells. Provide lagging extension to accommodate insulation thickness.

2.3.14 Pump Suction Strainers

Provide a cast iron strainer body, rated for not less than 25 psig at 100 degrees F, with flanges conforming to ASME B16.1, Class 125. Strainer construction is such that there is a machined surface joint between body and basket that is normal to the centerline of the basket.

Ensure minimum ratio of open area of each basket to pipe area is 3 to 1. Provide a basket with AISI 300 series corrosion-resistant steel wire mesh with perforated backing.

Ensure mesh is capable of retaining all particles larger than 1,000 micrometer, with a pressure drop across the strainer body of not more than 0.5 psi when the basket is two-thirds dirty at maximum system flow rate. Provide reducing fittings from strainer-flange size to pipe size.

Provide a differential-pressure gage fitted with a two-way brass cock across the strainer.

Provide manual air vent cocks in cap of each strainer.

2.3.15 Line Strainers, Water Service

Provide Y-type strainers with removable basket. Ensure strainers in sizes 2-inch ips and smaller have screwed ends; in sizes 2-1/2-inch ips and larger, strainers have flanged ends. Ensure body working-pressure rating exceeds maximum service pressure of installed system by at least 50 percent. Ensure body has cast-in arrows to indicate direction of flow. Ensure all strainer bodies fitted with screwed screen retainers have straight threads and gasketed with nonferrous metal. For strainer bodies 2-1/2-inches and larger, fitted with bolted-on screen retainers, provide offset blowdown holes. Fit all strainers larger than 2-1/2-inches with manufacturer's standard ball-type blowdown valve. Ensure body material is cast bronze conforming to ASTM B62. Where system material is nonferrous, use nonferrous metal for the metal strainer body material.

Ensure minimum free-hole area of strainer element is equal to not less than 3.4 times the internal area of connecting piping. Strainer screens perforation size is not to exceed 0.045-inch. Ensure strainer screens have finished ends fitted to machined screen chamber surfaces to preclude bypass flow. Strainer element material is AISI Type 304 corrosion-resistant steel.

2.4 VALVES

Submit equipment and performance data for valves consisting of corrosion

resistance and life expectancy. Submit design analysis and calculations consisting of rates of flow, head losses, inlet and outlet design, and pressure calculations. Also include in data, pipe dimensions, as well as temperature ratings, vibration and thrust limitations, minimum burst pressures, shut-off and non-shock pressures and weld characteristics.

Polypropylene valves will comply with the performance requirements of ASTM F2389. Valves shall conform to ASME B16.34.

2.4.1 Ball and Butterfly Valves

Ensure ball valves conform to MSS SP-72 for flanged valves and MSS SP-110 for screwed-end valves for Figure 1A 1 piece body, 1B vertically split body, 1C top entry 1D three piece body and are rated for service at not less than 175 psig at 200 degrees F. For valve bodies in sizes 2 inches and smaller, use screwed-end connection-type constructed of Class A copper alloy. For valve bodies in sizes 2-1/2 inches and larger, use flanged-end connection type, constructed of Class D material. Balls and stems of valves 2 inches and smaller are manufacturer's standard with hard chrome plating finish. Balls and stems of valves 2-1/2 inches and larger are manufacturer's standard Class C corrosion-resistant steel alloy with hard chrome plating. Balls of valves 6 inches and larger may be Class D with 900 Brinell hard chrome plating. Ensure valves are suitable for flow from either direction and seal equally tight in either direction. Valves with ball seals held in place by spring washers are not acceptable. Ensure all valves have adjustable packing glands. Seats and seals are fabricated from tetrafluoroethylene.

Ensure butterfly valves conform to MSS SP-67 and are the wafer type for mounting between specified flanges. Ensure valves are rated for 150-psig shutoff and nonshock working pressure. Select bodies of cast ferrous metal conforming to ASTM A126, Class B, and to ASME B16.1 for body wall thickness. Seats and seals are fabricated from resilient elastomer designed for field removal and replacement.

2.4.2 Drain, Vent, and Gage Cocks

Provide lever handle drain, vent, and gage cocks, ground key type, with washer and screw, constructed of polished ASTM B62 bronze, and rated 125-psi wsp. Ensure end connections are rated for specified service pressure.

Ensure pump vent cocks, and where spray control is required, are UL umbrella-hood type, constructed of manufacturer's standard polished brass. Ensure cocks are 1/2-inch ips male, end threaded, and rated at not less than 125 psi at 225 degrees F.

2.4.3 Gate Valves (GAV)

Ensure gate valves 2 inches and smaller conform to MSS SP-80. For valves located in tunnels, equipment rooms, factory-assembled equipment, and where indicated use union-ring bonnet, screwed-end type. Make packing of non-asbestos type materials. Use rising stem type valves.

Ensure gate valves 2-1/2 inches and larger, are Type I, (solid wedge disc, tapered seats, steam rated); Class 125 (125-psig steam-working pressure at 353 degrees F saturation); and 200-psig, wog (nonshock), conforming to MSS SP-70 and to requirements specified herein. Select flanged valves, with bronze trim and outside screw and yoke (OS&Y) construction. Make

packing of non-asbestos type materials.

2.4.4 Globe and Angle Valves (GLV-ANV)

Ensure globe and angle valves 2 inches and smaller, are 125-pound, 125-psi conforming to MSS SP-80 and to requirements specified herein. For valves located in tunnels, equipment rooms, factory-assembled equipment, and where indicated, use union-ring bonnet, screwed-end type. Ensure disc is free to swivel on the stem in all valve sizes. Composition seating-surface disc construction may be substituted for all metal-disc construction. Make packing of non-asbestos type materials. Ensure disk and packing are suitable for pipe service installed.

Ensure globe and angle valves, 2-1/2 inches and larger, are cast iron with bronze trim. Ensure valve bodies are cast iron conforming to ASTM A126, Class A, as specified for Class 1 valves under MSS SP-80. Select flanged valves in conformance with ASME B16.1. Valve construction is outside screw and yoke (OS&Y) type. Make packing of non-asbestos type materials.

2.4.5 Standard Check Valves (SCV)

Ensure standard check valves in sizes 2 inches and smaller are 125-psi swing check valves except as otherwise specified. Provide lift checks where indicated. Ensure swing-check pins are nonferrous and suitably hard for the service. Select composition type discs. Ensure the swing-check angle of closure is manufacturer's standard unless a specific angle is needed.

Use cast iron, bronze trim, swing type check valves in sizes 2-1/2 inches and larger. Ensure valve bodies are cast iron, conforming to ASTM A126, Class A and valve ends are flanged in conformance with ASME B16.1. Swing-check pin is AISI Type or approved equal corrosion-resistant steel. Angle of closure is manufacturer's standard unless a specific angle is needed. Ensure valves have bolted and gasketed covers.

Provide check valves with external spring-loaded , positive-closure devices and valve ends are mechanical joint .

2.4.6 Nonslam Check Valves (NSV)

Provide check valves at pump discharges in sizes 2 inches and larger with nonslam or silent-check operation conforming to MSS SP-125. Select a valve disc or plate that closes before line flow can reverse to eliminate slam and water-hammer due to check-valve closure. Ensure valve is Class 125 rated for 200-psi maximum, nonshock pressure at 150 degrees F in sizes to 12 inches. Use valves that are wafer type to fit between flanges conforming to ASME B16.1. Valve body may be cast iron, or equivalent strength ductile iron. Select disks using manufacturer's standard bronze, aluminum bronze, or corrosion-resistant steel. Ensure pins, springs, and miscellaneous trim are manufacturer's standard corrosion-resistant steel. Disk and shaft seals are Buna-N elastomer tetrafluoroethylene.

2.5 MISCELLANEOUS MATERIALS

Submit equipment and performance data for miscellaneous materials consisting of corrosion resistance, life expectancy, gage tolerances, and grade line analysis.

2.5.1 Bituminous Coating

Ensure the bituminous coating is a solvent cutback, heavy-bodied material to produce not less than a 12-mil dry-film thickness in one coat, and is recommended by the manufacturer to be compatible with factory-applied coating and rubber joints.

For previously coal-tar coated and uncoated ferrous surfaces underground, use bituminous coating solvent cutback coal-tar type, conforming to MIL-C-18480.

2.5.2 Bolting

Ensure flange and general purpose bolting is hex-head and conforms to ASTM A307, Grade B (bolts, for flanged joints in piping systems where one or both flanges are cast iron). Heavy hex-nuts conform to ASTM A563. Square-head bolts and nuts are not acceptable. Ensure threads are coarse-thread series.

2.5.3 Elastomer Caulk

Use two-component polysulfide- or polyurethane-base elastomer caulking material, conforming to ASTM C920.

2.5.4 Escutcheons

Manufacture escutcheons from nonferrous metals and chrome-plated except when AISI 300 series corrosion-resistant steel is provided. Ensure metals and finish conforms to ASME A112.19.2/CSA B45.1.

Use one-piece escutcheons where mounted on chrome-plated pipe or tubing, and one-piece of split-pattern type elsewhere. Ensure all escutcheons have provisions consisting of internal spring-tension devices for maintaining a fixed position against a surface.

2.5.5 Flashing

Ensure sheetlead conforms to ASTM B749, UNS Alloy Number L50049 (intended for use in laboratories and shops in general application).

Ensure sheet copper conforms to ASTM B370 and be not less than 16 ounces per square foot weight.

2.5.6 Flange Gaskets

Provide compressed non-asbestos sheets, conforming to ASTM F104, coated on both sides with graphite or similar lubricant, with nitrile composition, binder rated to 750 degrees F.

2.5.7 Grout

Provide shrink-resistant grout as a premixed and packaged metallic-aggregate, mortar-grouting compound conforming to ASTM C404 and ASTM C476.

Ensure shrink-resistant grout is a combination of pre-measured and packaged epoxy polyamide or amine resins and selected aggregate mortar grouting compound conforming to the following requirements:

Tensile strength		1,900 psi, minimum
Compressive strength	ASTM C109/C109M	14,000 psi, minimum
Shrinkage, linear		0.00012 inch per inch, maximum
Water absorption	ASTM C67/C67M	0.1 percent, maximum
Bond strength to		1,000 psi, minimum steel in shear minimum

2.5.8 Pipe Thread Compounds

Use polytetrafluoroethylene tape not less than 2 to 3 mils thick in potable and process water and in chemical systems for pipe sizes to and including 1-inch ips. Use polytetrafluoroethylene dispersions and other suitable compounds for all other applications upon approval by the Contracting Officer; however, do not use lead-containing compounds in potable water systems.

2.6 SUPPORTING ELEMENTS

Submit equipment and performance data for the supporting elements consisting of corrosion resistance, life expectancy, gage tolerances, and grade line analysis.

Provide all necessary piping systems and equipment supporting elements, including but not limited to: building structure attachments; supplementary steel; hanger rods, stanchions, and fixtures; vertical pipe attachments; horizontal pipe attachments; anchors; guides; and spring-cushion, variable, or constant supports. Ensure supporting elements are suitable for stresses imposed by systems pressures and temperatures and natural and other external forces normal to this facility without damage to supporting element system or to work being supported.

Ensure supporting elements conform to requirements of ASME B31.3, and MSS SP-58, except as noted.

Ensure attachments welded to pipe are made of materials identical to that of pipe or materials accepted as permissible raw materials by referenced code or standard specification.

Ensure supporting elements exposed to weather are hot-dip galvanized or stainless steel. Select materials of such a nature that their apparent and latent-strength characteristics are not reduced due to galvanizing process. Electroplate supporting elements in contact with copper tubing with copper.

Type designations specified herein are based on MSS SP-58. Ensure masonry anchor group-, type-, and style-combination designations are in accordance with CID A-A-1922, CID A-A-1923, CID A-A-1924, CID A-A-1925 , CID A-A-55614, and CID A-A-55615. Provide support elements, except for supplementary steel, that are cataloged, load rated, commercially manufactured products.

2.6.1 Building Structure Attachments

2.6.1.1 Anchor Devices, Concrete and Masonry

Ensure anchor devices conform to CID A-A-1922, CID A-A-1923, CID A-A-1924,

CID A-A-1925, CID A-A-55614, and CID A-A-55615

For cast-in, floor mounted, equipment anchor devices, provide adjustable positions.

Provide built-in masonry anchor devices.

Do not use powder-actuated anchoring devices to support any mechanical systems components.

2.6.1.2 Beam Clamps

Ensure beam clamps are center-loading MSS SP-58 Type 20 .

When it is not possible to use center-loading beam clamps, eccentric-loading beam clamps, MSS SP-58 Type 19 may be used for piping sizes 2 inches and less and for piping sizes 2 through 10 inches provided two counterbalancing clamps are used per point of pipe support. Where more than one rod is used per point of pipe support, determine rod diameter in accordance with referenced standards.

2.6.1.3 C-Clamps

Do not use C-clamps.

2.6.1.4 Inserts, Concrete

Use concrete MSS SP-58 Type 18 inserts When applied to piping in sizes 2 inches ips and larger and where otherwise required by imposed loads, insert and wire a 1-foot length of 1/2-inch reinforcing rod through wing slots. Submit proprietary-type continuous inserts for approval.

2.6.2 Horizontal Pipe Attachments

2.6.2.1 Single Pipes

Support piping in sizes to and including 2-inch ips by MSS SP-58 Type 6 solid malleable iron pipe rings, except that, use split-band-type rings in sizes up to 1-inch ips.

Support piping in sizes through 8-inch ips inclusive by MSS SP-58 Type 1 attachments.

Use MSS SP-58 Type 1 and Type 6 assemblies on vapor-sealed insulated piping and have an inside diameter larger than pipe being supported to provide adequate clearance during pipe movement.

Where thermal movement of a point in a piping system 4 inches and larger would cause a hanger rod to deflect more than 4 degrees from the vertical or where a horizontal point movement exceeds 1/2 inch, use MSS SP-58 Type 41 pipe rolls.

Support piping in sizes larger than 8-inch ips with MSS SP-58 Type 41 pipe rolls.

Use MSS SP-58 Type 40 shields on all insulated piping. Ensure area of the supporting surface is such that compression deformation of insulated surfaces does not occur. Roll away longitudinal and transverse shield edges from the insulation.

Provide insulated piping without vapor barrier on roll supports with MSS SP-58 Type 39 saddles.

Provide spring supports as indicated.

2.6.2.2 Parallel Pipes

Use trapeze hangers fabricated from structural steel shapes, with U-bolts, in congested areas and where multiple pipe runs occur. Ensure structural steel shapes conform to supplementary steel requirements.

2.6.3 Vertical Pipe Attachments

Ensure vertical pipe attachments are MSS SP-58 Type 8.

Include complete fabrication and attachment details of any spring supports in shop drawings.

2.6.4 Hanger Rods and Fixtures

Use only circular cross section rod hangers to connect building structure attachments to pipe support devices. Use pipe, straps, or bars of equivalent strength for hangers only where approved by the Contracting Officer.

Provide turnbuckles, swing eyes, and clevises as required by support system to accommodate temperature change, pipe accessibility, and adjustment for load and pitch. Rod couplings are not acceptable.

2.6.5 Supplementary Steel

Where it is necessary to frame structural members between existing members or where structural members are used in lieu of commercially rated supports, design and fabricate such supplementary steel in accordance with AISC 325.

PART 3 EXECUTION

3.1 PIPE INSTALLATION

Submit certificates for pipes, valves and specialties showing conformance with test requirements as contained in the reference standards contained in this section. Provide certificates verifying Surface Resistance, Shear and Tensile Strengths, Temperature Ratings, Bending Tests, Flattening Tests and Transverse Guided Weld Bend Tests.

Provide test reports for Hydrostatic Tests, Air Tests, Valve-Operating Tests, Drainage Tests, Pneumatic Tests, Non-Destructive Electric Tests and System Operation Tests, in compliance with referenced standards contained within this section.

Fabricate and install piping systems in accordance with ASME B31.3, MSS SP-58, and AWS WHB-2.9.

Submit Installation Drawings for pipes, valves and specialties. Drawings include the manufacturer's design and construction calculations, forces required to obtain rated axial, lateral, or angular movements, installation criteria, anchor and guide requirements for equipment, and

equipment room layout and design. Ensure drawings specifically advise on procedures to be followed and provisions required to protect expansion joints during specified hydrostatic testing operations.

Ensure connections between steel piping and copper piping are electrically isolated from each other. Dielectric pipe unions shall be installed to prevent galvanic corrosion. The dielectric unions shall have metal connections on both ends. The ends shall be threaded, flanged, or brazed to match adjacent piping. The metal parts of the union shall be separated so that the electrical current is below one percent of the galvanic current which would exist upon metal-to-metal contact. Gaskets, flanges, and unions shall be installed in accordance with manufacturer's recommendations.

Make final connections to equipment with unions installed every 100 feet of straight run. Install unions in the line downstream of screwed- and welded-end valves.

Ream all pipe ends before joint connections are made.

Make screwed joints with specified joint compound with not more than three threads showing after joint is made up.

Apply joint compounds to the male thread only and exercise care to prevent compound from reaching the unthreaded interior of the pipe.

Install screwed unions, welded unions, or bolted flanges wherever required to permit convenient removal of equipment, valves, and piping accessories from the piping system for maintenance.

Securely support piping systems with due allowance for thrust forces, thermal expansion and contraction. Do not subject the system to mechanical, chemical, vibrational or other damage as specified in ASME B31.3.

Ensure field welded joints conform to the requirements of the AWS WHB-2.9, ASME B31.3, and ASME BPVC SEC IX.

Make piping systems butt weld joints with backing rings. Use compatible backing ring materials with materials being joined. Ensure joint configuration conforms to ASME B16.25.

For polypropylene pipe, make fusion-weld joints in accordance with the pipe and fitting manufacturer's specifications and product standards. Use fusion-weld tooling, welding machines, and electrofusion devices specified by the pipe and fittings manufacturer. Prior to joining, prepare the pipe and fittings in accordance with ASTM F2389 and the manufacturer's specifications. Ensure joint preparation, setting and alignment, fusion process, cooling times and working pressure are in accordance with the pipe and fitting manufacturer's specifications.

Accomplish preheat and postheat treatment of welds in accordance with ASME BPVC SEC IX and ASME B31.3.

3.2 VALVES

Install valves in piping mains and all branches and at equipment where

indicated and as specified.

Install valves to permit isolation of branch piping and each equipment item from the balance of the system.

Install riser and downcomer drains above piping shutoff valves in piping 2-1/2 inches and larger. Tap and fit shutoff valve body with a 1/2-inch plugged globe valve.

Install valves unavoidably located in furred or other normally inaccessible places with access panels adequately sized for the location and located so that concealed items may be serviced, maintained, or replaced.

3.3 SUPPORTING ELEMENTS INSTALLATION

Install supporting elements in accordance with the referenced codes and standards.

Support piping from building structure. Do not support piping from roof deck or from other pipe.

Run piping parallel with the lines of the building. Space and install piping and components so that a threaded pipe fitting may be removed between adjacent pipes and so that there is no less than 1/2 inch of clear space between the finished surface and other work and between the finished surface of parallel adjacent piping. Arrange hangars on different adjacent service lines running parallel with each other in line with each other and parallel to the lines of the building.

Install piping support elements at intervals specified hereinafter, at locations not more than 3 feet from the ends of each runout, and not over 1 foot from each change in direction of piping.

Base load rating for all pipe-hanger supports on insulated weight of lines filled with water and forces imposed. Deflection per span is not exceed slope gradient of pipe. Ensure supports are in accordance with the following minimum rod size and maximum allowable hanger spacing for specified pipe. For concentrated loads such as valves, reduce the allowable span proportionately:

<u>PIPE SIZE</u> <u>INCHES</u>	<u>ROD SIZE</u> <u>INCHES</u>	<u>STEEL PIPE</u> <u>FEET</u>	<u>COPPER PIPE</u> <u>FEET</u>
1 and smaller	3/8	8	6
1-1/4 to 1-1/2	3/8	10	8
2	3/8	10	8
2-1/2 to 3-1/2	1/2	12	12
4 to 5	5/8	16	14
6	3/4	16	16
8 to 12	7/8	20	20
14 to 18	1	20	20

<u>PIPE SIZE</u> <u>INCHES</u>	<u>ROD SIZE</u> <u>INCHES</u>	<u>STEEL PIPE</u> <u>FEET</u>	<u>COPPER PIPE</u> <u>FEET</u>
20 and over	1-1/4	20	20

Install vibration isolation supports where needed. Refer to Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT where A/C equipment and piping is installed.

Support vertical risers independently of connected horizontal piping, whenever practicable, with fixed or spring supports at the base and at intervals to accommodate system range of thermal conditions. Ensure risers have guides for lateral stability. For risers subject to expansion, install only one rigid support at a point approximately one-third down from the top. Place clamps under fittings unless otherwise specified. Support carbon-steel pipe at each floor and at not more than 15-foot intervals for pipe 2 inches and smaller and at not more than 20-foot intervals for pipe 2-1/2 inches and larger.

3.4 PENETRATIONS

Install effective sound stopping and adequate operating clearance to prevent structure contact where piping penetrates walls, floors, or ceilings into occupied spaces adjacent to equipment rooms; where similar penetrations occur between occupied spaces; and where penetrations occur from pipe chases into occupied spaces. Occupied spaces include space above ceilings where no special acoustic treatment of ceiling is provided. Finish penetrations to be compatible with surface being penetrated.

Accomplish sound stopping and vapor-barrier sealing of pipe shafts and large floor and wall openings by packing to high density with properly supported fibrous-glass insulation or, where ambient or surface temperatures do not exceed 120 degrees F, by foaming-in-place with self-extinguishing, 2-pound density polyurethane foam to a depth not less than 6 inches. Finish foam with a rasp. Ensure vapor barrier is not less than 1/8-inch thick vinyl coating applied to visible and accessible surfaces. Where high temperatures and fire stopping are a consideration, use only mineral wool with openings covered by 16-gage sheet metal.

3.5 SLEEVES

Install sleeves where piping passes through roofs, masonry, concrete walls and floors.

Continuously weld sleeves passing through steel decks to the deck.

Ensure sleeves that extend through floors, roofs, load bearing walls, and fire barriers are continuous and fabricated from Schedule 40 steel pipe, with welded anchor lugs. Form all other sleeves by molded linear polyethylene liners or similar materials that are removable. Ensure diameter of sleeves is large enough to accommodate pipe, insulation, and jacketing without touching the sleeve and provides a minimum 3/8-inch clearance. Install a sleeve size to accommodate mechanical and thermal motion of pipe precluding transmission of vibration to walls and the generation of noise.

Pack the space between a pipe, bare or insulated, and the inside of a pipe sleeve or a construction surface penetration solid with a mineral fiber

conforming to ASTM C553 Type V (flexible blanket), to 1,000 degrees F. Install this packing wherever the piping passes through firewalls, equipment room walls, floors, and ceilings connected to occupied spaces, and other locations where sleeves or construction-surface penetrations occur between occupied spaces. Where sleeves or construction surface penetrations occur between conditioned and unconditioned spaces, fill the space between a pipe, bare or insulated, and the inside of a pipe sleeve or construction surface penetration with an elastomer caulk to a depth of 1/2 inch. Ensure all caulked surfaces are oil- and grease-free.

Ensure through-penetration fire stop materials and methods are in accordance with ASTM E814 and UL 1479.

Caulk exterior wall sleeves watertight with lead and oakum or mechanically expandable chloroprene inserts with mastic-sealed metal components.

Ensure sleeve height above roof surface is a minimum of 12 and a maximum of 18-inches.

3.6 ESCUTCHEONS

Install escutcheons at all penetrations of piping into finished areas. Where finished areas are separated by partitions through which piping passes, install escutcheons on both sides of the partition. Where suspended ceilings are installed, install plates at the underside only of such ceilings. For insulated pipes, select plates large enough to fit around the insulation. Use chrome-plated escutcheons in all occupied spaces and of size sufficient to effectively conceal openings in building construction. Firmly attach escutcheons with setscrews.

3.7 FLASHINGS

Install flashings at penetrations of building boundaries by mechanical systems and related work.

3.8 UNDERGROUND PIPING INSTALLATION

Prior to being lowered into a trench, clean all piping, visually inspected for apparent defects, and tapped with a hammer to audibly detect hidden defects.

Further inspect suspect cast-ferrous piping by painting with kerosene on external surfaces to reveal cracks.

Distinctly mark defective materials found using a road-traffic quality yellow paint; promptly remove defective material from the site.

After conduit has been inspected, and not less than 48 hours prior to being lowered into a trench, coat all external surfaces of cast ferrous conduit with a compatible bituminous coating for protection against brackish ground water. Apply a single coat, in accordance with the manufacturer's instructions, to result in a dry-film thickness of not less than 12 mils.

Ensure excavations are dry and clear of extraneous materials when pipe is being laid.

Use wheel cutters for cutting of piping or other machines designed specifically for that purpose. Electric-arc and oxyacetylene cutting is

not permitted.

Begin laying of pipe at the low point of a system. When in final acceptance position, ensure it is true to the grades and alignment indicated, with unbroken continuity of invert. Blocking and wedging is not permitted.

Point bell or grooved ends of piping upstream.

Make changes in direction with long sweep fittings.

Install necessary socket clamping, piers, bases, anchors, and thrust blocking. Protect rods, clamps, and bolting with a coating of bitumen.

Support underground piping below supported or suspended slabs from the slab with a minimum of two supports per length of pipe. Protect supports with a coating of bitumen.

On excavations that occur near and below building footings, install backfilling material consisting of 2,000-psi cured compressive-strength concrete poured or pressure-grouted up to the level of the footing.

Properly support vertical downspouts; soil, waste, and vent stacks; water risers; and similar work on approved piers at the base and provided with approved structural supports attached to building construction.

Provide cleanout, flushing, and observation risers.

3.9 HEAT TRACE CABLE INSTALLATION

Field apply heater tape and cut to fit as necessary, linearly along the length of pipe after piping has been pressure tested and approved by the Contracting Officer. Secure the heater to piping with cable ties. Label thermal insulation on the outside, "Electrical Heat Trace."

Install power connection, end seals, splice kits and tee kit components in accordance with IEEE 515 to provide a complete workable system. Terminate connection to the thermostat and ends of the heat tape in a junction box. Ensure cable and conduit connections are raintight.

3.10 DISINFECTION

Disinfect water piping, including all valves, fittings, and other devices, with a solution of chlorine and water. Ensure the solution contains not less than 50 parts per million (ppm) of available chlorine. Hold solution for a period of not less than 8 hours, after which the solution contains not less than 10 ppm of available chlorine or re-disinfect the piping. After successful sterilization, thoroughly flush the piping before placing into service. Flushing is complete when the flush water contains less than 0.5 ppm of available chlorine. Water for disinfected will be furnished by the Government. Approve disposal of contaminated flush water in accordance with written instructions received from the Environmental authority having jurisdiction through the Contracting Officer and all local, State and Federal Regulations.

3.11 HEAT TRACE CABLE TESTS

Test heat trace cable system in accordance with IEEE 515 after installation and before and after installation of the thermal insulation.

Test heater cable using a 1000 vdc megger. Minimum insulation resistance is 20 to 1000 megohms regardless of cable length.

3.12 OPERATION AND MAINTENANCE

Provide Operation and Maintenance Manuals consistent with manufacturer's standard brochures, schematics, printed instructions, general operating procedures and safety precautions. Submit test data that is clear and readily legible.

3.13 PAINTING OF NEW EQUIPMENT

Factory or shop apply new equipment painting, as specified herein, and provided under each individual section.

3.13.1 Factory Painting Systems

Manufacturer's standard factory painting systems may be provided subject to certification that the factory painting system applied withstands 125 hours in a salt-spray fog test, except that equipment located outdoors withstand 500 hours in a salt-spray fog test. Conduct salt-spray fog test is in accordance with ASTM B117, and for that test the acceptance criteria is as follows: immediately after completion of the test, the inspected paint shows no signs of blistering, wrinkling, or cracking, and no loss of adhesion; and the specimen shows no signs of rust creepage beyond 0.125 inch on either side of the scratch mark.

Ensure the film thickness of the factory painting system applied on the equipment is not less than the film thickness used on the test specimen. If manufacturer's standard factory painting system is being proposed for use on surfaces subject to temperatures above 120 degrees F, design the factory painting system for the temperature service.

3.13.2 Shop Painting Systems for Metal Surfaces

Clean, pretreat, prime and paint metal surfaces; except aluminum surfaces need not be painted. Apply coatings to clean dry surfaces. Clean the surfaces to remove dust, dirt, rust, oil and grease by wire brushing and solvent degreasing prior to application of paint, except clean to bare metal, surfaces subject to temperatures in excess of 120 degrees F.

Where more than one coat of paint is specified, apply the second coat after the preceding coat is thoroughly dry. Lightly sand damaged painting and retouch before applying the succeeding coat. Selected color of finish coat is aluminum or light gray.

- a. Temperatures Less Than 120 Degrees F: Immediately after cleaning, the metal surfaces subject to temperatures less than 120 degrees F receives one coat of pretreatment primer applied to a minimum dry film thickness of 0.3 mil, one coat of primer applied to a minimum dry film thickness of one mil; and two coats of enamel applied to a minimum dry film thickness of one mil per coat.
- b. Temperatures Between 120 and 400 Degrees F: Metal surfaces subject to temperatures between 120 and 400 degrees F Receives two coats of 400 degrees F heat-resisting enamel applied to a total minimum thickness of 2 mils.
- c. Temperatures Greater Than 400 Degrees F: Metal surfaces subject to

temperatures greater than 400 degrees F receives two coats of 600 degrees F heat-resisting paint applied to a total minimum dry film thickness of 2 mils.

-- End of Section --

SECTION 23 05 93

TESTING, ADJUSTING, AND BALANCING FOR HVAC
11/15

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ACOUSTICAL SOCIETY OF AMERICA (ASA)

ASA S1.4 (1983; Amendment 1985; R 2006)
Specification for Sound Level Meters (ASA 47)

ASA S1.11 PART 1 (2014) American National Standard
Electroacoustics - Octave-Band and
Fractional-Octave-Band Filters - Part 1:
Specifications

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING
ENGINEERS (ASHRAE)

ASHRAE HVAC APP IP HDBK (2016) HVAC Applications Handbook, I-P
Edition

ASSOCIATED AIR BALANCE COUNCIL (AABC)

AABC MN-1 (2002; 6th ed) National Standards for
Total System Balance

AABC MN-4 (1996) Test and Balance Procedures

NATIONAL ENVIRONMENTAL BALANCING BUREAU (NEBB)

NEBB MASV (2006) Procedural Standards for
Measurements and Assessment of Sound and
Vibration

NEBB PROCEDURAL STANDARDS (2015) Procedural Standards for TAB
(Testing, Adjusting and Balancing)
Environmental Systems

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION
(SMACNA)

SMACNA 1780 (2002) HVAC Systems - Testing, Adjusting
and Balancing, 3rd Edition

SMACNA 1858 (2004) HVAC Sound And Vibration Manual -
First Edition

SMACNA 1972 CD (2012) HVAC Air Duct Leakage Test Manual -
2nd Edition

1.2 DEFINITIONS

- a. AABC: Associated Air Balance Council
- b. COTR: Contracting Officer's Technical Representative
- c. DALT: Duct air leakage test
- d. DALT'd: Duct air leakage tested
- e. HVAC: Heating, ventilating, and air conditioning; or heating, ventilating, and cooling
- f. NEBB: National Environmental Balancing Bureau
- g. Out-of-tolerance data: Pertains only to field acceptance testing of Final DALT or TAB report. When applied to DALT work, this phase means When applied to TAB work this phase means "a measurement taken during TAB field acceptance testing which does not fall within the range of plus 5 to minus 5 percent of the original measurement reported on the TAB Report for a specific parameter."
- h. Season of maximum heating load: The time of year when the outdoor temperature at the project site remains within plus or minus 30 degrees Fahrenheit of the project site's winter outdoor design temperature, throughout the period of TAB data recording.
- i. Season of maximum cooling load: The time of year when the outdoor temperature at the project site remains within plus or minus 5 degrees Fahrenheit of the project site's summer outdoor design temperature, throughout the period of TAB data recording.
- j. Season 1, Season 2: Depending upon when the project HVAC is completed and ready for TAB, Season 1 is defined, thereby defining Season 2. Season 1 could be the season of maximum heating load, or the season of maximum cooling load.
- k. Sound measurements terminology: Defined in AABC MN-1, NEBB MASV, or SMACNA 1858 (TABB).
- l. TAB: Testing, adjusting, and balancing (of HVAC systems)
- m. TAB'd: HVAC Testing/Adjusting/Balancing procedures performed
- n. TAB Agency: TAB Firm
- r. TABB: Testing Adjusting and Balancing Bureau

1.2.1 Similar Terms

In some instances, terminology differs between the Contract and the TAB Standard primarily because the intent of this Section is to use the industry standards specified, along with additional requirements listed herein to produce optimal results.

The following table of similar terms is provided for clarification only. Contract requirements take precedent over the corresponding AABC, NEBB, or TABB requirements where differences exist.

SIMILAR TERMS			
Contract Term	AABC Term	NEBB Term	TABB Term
TAB Standard	National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems	Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems	International Standards for Environmental Systems Balance
TAB Specialist	TAB Engineer	TAB Supervisor	TAB Supervisor
Systems Readiness Check	Construction Phase Inspection	Field Readiness Check & Preliminary Field Procedures	Field Readiness Check & Prelim. Field Procedures

1.3 WORK DESCRIPTION

The work includes duct air leakage testing (DALT) and testing, adjusting, and balancing (TAB) of new heating, ventilating, and cooling (HVAC) air distribution systems including equipment and performance data, ducts, and piping which are located within, on, under, between, and adjacent to buildings.

Perform TAB in accordance with the requirements of the TAB procedural standard recommended by the TAB trade association that approved the TAB Firm's qualifications. Comply with requirements of AABC MN-1, NEBB PROCEDURAL STANDARDS, or SMACNA 1780 (TABB) as supplemented and modified by this specification section. All recommendations and suggested practices contained in the TAB procedural standards are considered mandatory.

Conduct DALT and TAB of the indicated existing systems and equipment and submit the specified DALT and TAB reports for approval. Conduct DALT testing in compliance with the requirements specified in SMACNA 1972 CD, except as supplemented and modified by this section. Conduct DALT and TAB work in accordance with the requirements of this section.

1.3.1 Air Distribution Systems

Test, adjust, and balance system (TAB) in compliance with this section. Obtain Contracting Officer's written approval before applying insulation to exterior of air distribution systems as specified under Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

1.3.2 Water Distribution Systems

TAB system in compliance with this section. Obtain Contracting Officer's written approval before applying insulation to water distribution systems as specified under Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. At Contractor's option and with Contracting Officer's written approval, the piping systems may be insulated before systems are TAB'd.

Terminate piping insulation immediately adjacent to each flow control

valve, automatic control valve, or device. Seal the ends of pipe insulation and the space between ends of pipe insulation and piping, with waterproof vapor barrier coating.

After completion of work under this section, insulate the flow control valves and devices as specified under Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

1.3.3 TAB SCHEMATIC DRAWINGS

Show the following information on TAB Schematic Drawings:

1. A unique number or mark for each piece of equipment or terminal.
2. Air quantities at air terminals.
3. Air quantities and temperatures in air handling unit schedules.
4. Water quantities and temperatures in thermal energy transfer equipment schedules.
5. Water quantities and heads in pump schedules.
6. Water flow measurement fittings and balancing fittings.
7. Ductwork Construction and Leakage Testing Table that defines the DALT test requirements, including each applicable HVAC duct system ID or mark, duct pressure class, duct seal class, and duct leakage test pressure. This table is included in the file for Graphics for Unified Facilities Guide Specifications:
<http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/forms-gra>

Submit three copies of the TAB Schematic Drawings and Report Forms to the Contracting Officer, no later than 21 days prior to the start of TAB field measurements.

1.3.4 Related Requirements

1.4 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

SD-02 Shop Drawings

TAB Schematic Drawings and Report Forms; G

SD-03 Product Data

Equipment and Performance Data; G

SD-06 Test Reports

Completed Pre-Final DALT Report; G

Certified Final DALT Report; G

SD-07 Certificates

Independent TAB Agency and Personnel Qualifications; G

1.5 QUALITY ASSURANCE

1.5.1 Independent TAB Agency and Personnel Qualifications

To secure approval for the proposed agency, submit information certifying that the TAB agency is a first tier subcontractor who is not affiliated with any other company participating in work on this contract, including design, furnishing equipment, or construction. Further, submit the following, for the agency, to Contracting Officer for approval:

a. Independent AABC or NEBB or TABB TAB agency:

TAB agency: AABC registration number and expiration date of current certification; or NEBB certification number and expiration date of current certification; or TABB certification number and expiration date of current certification.

TAB team supervisor: Name and copy of AABC or NEBB or TABB TAB supervisor certificate and expiration date of current certification.

TAB team field leader: Name and documented evidence that the team field leader has satisfactorily performed full-time supervision of TAB work in the field for not less than 3 years immediately preceding this contract's bid opening date.

TAB team field technicians: Names and documented evidence that each field technician has satisfactorily assisted a TAB team field leader in performance of TAB work in the field for not less than one year immediately preceding this contract's bid opening date.

Current certificates: Registrations and certifications are current, and valid for the duration of this contract. Renew Certifications which expire prior to completion of the TAB work, in a timely manner so that there is no lapse in registration or certification. TAB agency or TAB team personnel without a current registration or current certification are not to perform TAB work on this contract.

- b. TAB Team Members: TAB team approved to accomplish work on this contract are full-time employees of the TAB agency. No other personnel is allowed to do TAB work on this contract.
- c. Replacement of TAB team members: Replacement of members may occur if each new member complies with the applicable personnel qualifications and each is approved by the Contracting Officer.

PART 2 PRODUCTS

Not Used

PART 3 EXECUTION

3.1 WORK DESCRIPTIONS OF PARTICIPANTS

Comply with requirements of this section.

3.2 PRE-DALT/TAB MEETING

Meet with the Contracting Officer's technical representative (COTR) to develop a mutual understanding relative to the details of the DALT work and TAB work requirements. Ensure that the TAB supervisor is present at this meeting. Requirements to be discussed include required submittals, work schedule, and field quality control.

3.3 DALT PROCEDURES

3.3.1 Instruments, Consumables and Personnel

Provide instruments, consumables and personnel required to accomplish the DALT field work. Follow the same basic procedure specified below for TAB Field Work, including maintenance and calibration of instruments, accuracy of measurements, preliminary procedures, field work, workmanship and treatment of deficiencies. Calibrate and maintain instruments in accordance with manufacturer's written procedures.

3.3.2 [Enter Appropriate Subpart Title Here]

On completion of the installation of each duct system indicated to be DALT'd, notify the Contracting Officer in writing prior to the COTR's duct selection field visit.

3.3.3 Ductwork To Be DALT'd

From each duct system indicated as subject to DALT, the COTR will randomly select sections of each completed duct system for testing by the Contractor's TAB Firm. The sections selected will not exceed 20 percent of the total measured linear footage of duct systems indicated as subject to DALT. Sections of duct systems subject to DALT will include 20 percent of main ducts, branch main ducts, branch ducts and plenums for supply, return, exhaust, and plenum ductwork.

3.3.4 DALT Testing

Perform DALT on the HVAC duct sections of each system as selected by the COTR. Use the duct class, seal class, leakage class and the leak test pressure data indicated on the drawings, to comply with the procedures specified in SMACNA 1972 CD.

In spite of specifications of SMACNA 1972 CD to the contrary, DALT ductwork of construction class of 3-inch water gauge static pressure and below if indicated to be DALT'd. Complete DALT work on the COTR selected ductwork within 48 hours after the particular ductwork was selected for DALT. Separately conduct DALT work for large duct systems to enable the DALT work to be completed in 48 hours.

3.3.5 Completed Pre-Final DALT Report

3.3.6 Quality Assurance - COTR DALT Field Acceptance Testing

In the presence of the COTR and TAB team field leader, verify for accuracy Pre-final DALT Report data selected by the COTR. For each duct system, this acceptance testing shall be conducted on a maximum of 50 percent of the duct sections DALT'd.

Further, if any data on the Pre-final DALT report form for a given duct section is out-of-tolerance, then field acceptance testing shall be conducted on data for one additional duct section, preferably in the same duct system, in the presence of the COTR.

3.3.7 Additional COTR Field Acceptance Testing

If any of the duct sections checked for a given system are determined to have a leakage rate measured that exceeds the leakage rate allowed by SMACNA Leak Test Manual for an indicated duct construction class and sealant class, terminate data checking for that section. The associated Pre-final DALT Report data for the given duct system will be disapproved. Make the necessary corrections and prepare a revised Pre-final DALT Report. Reschedule a field check of the revised report data with the COTR.

3.3.8 Certified Final DALT Report

3.3.9 Prerequisite for TAB Field Work

Do not commence TAB field work prior to the completion and approval, for all systems, of the Final DALT Report.

3.4 TAB PROCEDURES

3.4.1 TAB Field Work

Test, adjust, and balance the HVAC systems until measured flow rates (air and water flow) are within plus or minus 5 percent of the design flow rates as specified or indicated on the contract documents.

That is, comply with the the requirements of AABC MN-1 or SMACNA 1780 (TABB) and SMACNA 1858 (TABB), except as supplemented and modified by this section.

Provide instruments and consumables required to accomplish the TAB work. Calibrate and maintain instruments in accordance with manufacturer's written procedures.

Test, adjust, and balance the HVAC systems until measured flow rates (air and water flow) are within plus or minus 5 percent of the design flow rates as specified or indicated on the contract documents. Conduct TAB work, including measurement accuracy, and sound measurement work in conformance with the AABC MN-1 and AABC MN-4, or NEBB TABES and NEBB MASV, or SMACNA 1780 (used by TABB) and SMACNA 1858 sound measurement procedures, except as supplemented and modified by this section. The only water flow and air flow reporting which can be deferred until the Season 2 is that data which would be affected in terms of accuracy due to outside ambient conditions.

3.4.2 Preliminary Procedures

Use the approved pre-field engineering report as instructions and procedures for accomplishing TAB field work. TAB engineer is to locate, in the field, test ports required for testing. It is the responsibility of the sheet metal contractor to provide and install test ports as required by the TAB engineer.

3.4.3 TAB Air Distribution Systems

3.4.3.1 Units With Coils

Report heating and cooling performance capacity tests for hot water, chilled water, DX and steam coils for the purpose of verifying that the coils meet the indicated design capacity. Submit the following data and calculations with the coil test reports:

- a. For air handlers with capacities greater than 7.5 tons (90,000 Btu) cooling, such as factory manufactured units, central built-up units and rooftop units, conduct capacity tests in accordance with AABC MN-4, procedure 3.5, "Coil Capacity Testing."

Do not determine entering and leaving wet and dry bulb temperatures by single point measurement, but by the average of multiple readings in compliance with paragraph 3.5-5, "Procedures", (in subparagraph d.) of AABC MN-4, Procedure 3.5, "Coil Capacity Testing."

Submit part-load coil performance data from the coil manufacturer converting test conditions to design conditions; use the data for the purpose of verifying that the coils meet the indicated design capacity in compliance with AABC MN-4, Procedure 3.5, "Coil Capacity Testing," paragraph 3.5.7, "Actual Capacity Vs. Design Capacity" (in subparagraph c.).

- b. For units with capacities of 7.5 tons (90,000 Btu) or less, such as fan coil units, duct mounted reheat coils associated with VAV terminal units, and unitary units, such as through-the-wall heat pumps:

Determine the apparent coil capacity by calculations using single point measurement of entering and leaving wet and dry bulb temperatures; submit the calculations with the coil reports.

3.4.3.2 Air Handling Units

Air handling unit systems including fans (air handling unit fans, exhaust fans and winter ventilation fans), coils, ducts, plenums, mixing boxes, terminal units, variable air volume boxes, and air distribution devices for supply air, return air, outside air, mixed air relief air, and makeup

air.

3.4.3.3 Rooftop Air Conditioning

Rooftop air conditioning systems including fans, coils, ducts, plenums, and air distribution devices for supply air, return air, and outside air.

For refrigeration compressors/condensers/condensing units/evaporators, report data as required by NEBB, AABC, and TABB standard procedures, including refrigeration operational data.

3.4.3.4 Heating and Ventilating Units

Heating and ventilating unit systems including fans, coils, ducts, plenums, roof vents, registers, diffusers, grilles, and louvers for supply air, return air, outside air, and mixed air.

3.4.3.5 Makeup Air Units

Makeup air unit systems including fans, coils, ducts, plenums, registers, diffusers, grilles, and louvers for supply air, return air, outside air, and mixed air.

3.4.3.6 Exhaust Fans

Exhaust fan systems including fans, ducts, plenums, grilles, and hoods for exhaust air.

3.4.4 TAB Water Distribution Systems

3.4.4.1 Heating Hot Water

Heating hot water systems including boilers, hot water converters (e.g., heat exchangers), pumps, coils, system balancing valves and flow measuring devices.

3.4.4.2 Dual Temperature Water

Dual temperature water systems including boilers , pumps, coils, and system balancing valves, and flow measuring devices.

3.4.5 Sound Measurement Work

3.4.5.1 Areas To Be Sound Measured

In the following spaces, measure and record the sound power level for each octave band listed in ASHRAE HVAC APP IP HDBK Noise Criteria:

- a. All HVAC mechanical rooms, including machinery spaces and other spaces containing HVAC power drivers and power driven equipment.
- b. All spaces sharing a common barrier with each mechanical room, including rooms overhead, rooms on the other side of side walls, and rooms beneath the mechanical room floor.

3.4.5.2 Procedure

Measure sound levels in each room, when unoccupied except for the TAB team, with all HVAC systems that would cause sound readings in the room

operating in their noisiest mode. Record the sound level in each octave band. Attempt to mitigate the sound level and bring the level to within the specified ASHRAE HVAC APP IP HDBK noise criteria goals, if such mitigation is within the TAB team's control. State in the report the ASHRAE HVAC APP IP HDBK noise criteria goals. If sound level cannot be brought into compliance, provide written notice of the deficiency to the Contractor for resolution or correction.

3.4.5.3 Timing

Measure sound levels at times prescribed by AABC or NEBB or TABB.

3.4.5.4 Meters

Measure sound levels with a sound meter complying with ASA S1.4, Type 1 or 2, and an octave band filter set complying with ASA S1.11 PART 1. Use measurement methods for overall sound levels and for octave band sound levels as prescribed by NEBB.

3.4.5.5 Calibration

Calibrate sound levels as prescribed by AABC or NEBB or TABB, except that calibrators emitting a sound pressure level tone of 94 dB at 1000 hertz (Hz) are also acceptable.

3.4.5.6 Background Noise Correction

Determine background noise component of room sound (noise) levels for each (of eight) octave bands as prescribed by AABC or NEBB or TABB.

3.4.6 TAB Work on Performance Tests Without Seasonal Limitations

3.4.6.1 Performance Tests

In addition to the TAB proportionate balancing work on the air distribution systems and the water distribution systems, accomplish TAB work on the HVAC systems which directly transfer thermal energy. TAB the operational performance of the heating systems and cooling systems.

3.4.6.2 Ambient Temperatures

On each tab report form used for recording data, record the outdoor and indoor ambient dry bulb temperature range and the outdoor and indoor ambient wet bulb temperature range within which the report form's data was recorded. Record these temperatures at beginning and at the end of data taking.

3.4.7 TAB Work on Performance Tests With Seasonal Limitations

3.4.7.1 Performance Tests

3.4.7.2 Season Of Maximum Load

3.4.7.3 Ambient Temperatures

On each tab report form used for recording data, record the outdoor and indoor ambient dry bulb temperature range and the outdoor and indoor ambient wet bulb temperature range within which the report form's data was recorded. Record these temperatures at beginning and at the end of data taking.

3.4.7.4 Sound Measurements

Comply with the paragraph SOUND MEASUREMENT WORK, specifically, the requirement that a room must be operating in its noisiest mode at the time of sound measurements in the room. The maximum noise level measurements could depend on seasonally related heat or cooling transfer equipment.

3.4.8 Workmanship

Conduct TAB work on the HVAC systems until measured flow rates are within plus or minus 5 percent of the design flow rates as specified or indicated on the contract documents. This TAB work includes adjustment of balancing valves, balancing dampers, and sheaves. Further, this TAB work includes changing out fan sheaves and pump impellers if required to obtain air and water flow rates specified or indicated. If, with these adjustments and equipment changes, the specified or indicated design flow rates cannot be attained, contact the Contracting Officer for direction.

3.4.9 Deficiencies

Strive to meet the intent of this section to maximize the performance of the equipment as designed and installed. However, if deficiencies in equipment design or installation prevent TAB work from being accomplished within the range of design values specified in the paragraph WORKMANSHIP, provide written notice as soon as possible to the Contractor and the Contracting Officer describing the deficiency and recommended correction.

Responsibility for correction of installation deficiencies is the Contractor's. If a deficiency is in equipment design, call the TAB team supervisor for technical assistance. Responsibility for reporting design deficiencies to Contractor is the TAB team supervisor's.

3.4.10 TAB Reports

3.4.11 Quality Assurance - COTR TAB Field Acceptance Testing

3.4.11.1 TAB Field Acceptance Testing

During the field acceptance testing, verify, in the presence of the COTR, random selections of data (water, air quantities, air motion,) recorded in the TAB Report. Points and areas for field acceptance testing are to

be selected by the COTR. Measurement and test procedures are the same as approved for TAB work for the TAB Report.

Field acceptance testing includes verification of TAB Report data recorded for the following equipment groups:

Group 1: All chillers, boilers, return fans, computer room units, and air handling units (rooftop and central stations).

Group 2: 25 percent of the VAV terminal boxes and associated diffusers and registers.

Group 3: 25 percent of the supply diffusers, registers, grilles associated with constant volume air handling units.

Group 4: 25 percent of the return grilles, return registers, exhaust grilles and exhaust registers.

Group 5: 25 percent of the supply fans, exhaust fans, and pumps.

Further, if any data on the TAB Report for Groups 2 through 5 is found not to fall within the range of plus 5 to minus 5 percent of the TAB Report data, additional group data verification is required in the presence of the COTR. Verify TAB Report data for one additional piece of equipment in that group. Continue this additional group data verification until out-of-tolerance data ceases to be found.

3.4.11.2 Additional COTR TAB Field Acceptance Testing

If any of the acceptance testing measurements for a given equipment group is found not to fall within the range of plus 5 to minus 5 percent of the TAB Report data, terminate data verification for all affected data for that group. The affected data for the given group will be disapproved. Make the necessary corrections and prepare a revised TAB Report. Reschedule acceptance testing of the revised report data with the COTR.

3.4.11.3 Prerequisite for Approval

Compliance with the field acceptance testing requirements of this section is a prerequisite for the final Contracting Officer approval of the TAB Report submitted.

3.5 MARKING OF SETTINGS

Upon the final TAB work approval, permanently mark the settings of HVAC adjustment devices including valves, gauges, splitters, and dampers so that adjustment can be restored if disturbed at any time. Provide permanent markings clearly indicating the settings on the adjustment devices which result in the data reported on the submitted TAB report.

3.6 MARKING OF TEST PORTS

The TAB team is to permanently and legibly mark and identify the location points of the duct test ports. If the ducts have exterior insulation, make these markings on the exterior side of the duct insulation. Show the location of test ports on the as-built mechanical drawings with dimensions given where the test port is covered by exterior insulation.

-- End of Section --

SECTION 23 07 00

THERMAL INSULATION FOR MECHANICAL SYSTEMS
02/13, CHG 7: 05/20

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only. At the discretion of the Government, the manufacturer of any material supplied will be required to furnish test reports pertaining to any of the tests necessary to assure compliance with the standard or standards referenced in this specification.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING
ENGINEERS (ASHRAE)

ASHRAE 90.2 (2018; Addenda A-B 2021; Addenda C-K 2023; Addenda L 2024) Energy-Efficient Design of Low-Rise Residential Buildings

ASTM INTERNATIONAL (ASTM)

ASTM A167 (2011) Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip

ASTM A240/A240M (2023a) Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

ASTM A580/A580M (2023) Standard Specification for Stainless Steel Wire

ASTM B209 (2014) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

ASTM C195 (2007; R 2013) Standard Specification for Mineral Fiber Thermal Insulating Cement

ASTM C450 (2008) Standard Practice for Fabrication of Thermal Insulating Fitting Covers for NPS Piping, and Vessel Lagging

ASTM C533 (2017; R 2023) Standard Specification for Calcium Silicate Block and Pipe Thermal Insulation

ASTM C534/C534M (2023) Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form

ASTM C547 (2022a) Standard Specification for Mineral

Fiber Pipe Insulation

ASTM C552	(2022) Standard Specification for Cellular Glass Thermal Insulation
ASTM C591	(2022) Standard Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation
ASTM C610	(2017; R 2023) Standard Specification for Molded Expanded Perlite Block and Pipe Thermal Insulation
ASTM C647	(2008; R 2013) Properties and Tests of Mastics and Coating Finishes for Thermal Insulation
ASTM C755	(2019b) Standard Practice for Selection of Water Vapor Retarders for Thermal Insulation
ASTM C795	(2008; R 2023) Standard Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel
ASTM C916	(2020) Standard Specification for Adhesives for Duct Thermal Insulation
ASTM C920	(2018) Standard Specification for Elastomeric Joint Sealants
ASTM C921	(2010; R 2015) Standard Practice for Determining the Properties of Jacketing Materials for Thermal Insulation
ASTM C1126	(2018) Standard Specification for Faced or Unfaced Rigid Cellular Phenolic Thermal Insulation
ASTM C1136	(2023) Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation
ASTM C1710	(2011) Standard Guide for Installation of Flexible Closed Cell Preformed Insulation in Tube and Sheet Form
ASTM D882	(2012) Tensile Properties of Thin Plastic Sheeting
ASTM D2863	(2019) Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
ASTM D5590	(2017; R 2021) Standard Test Method for Determining the Resistance of Paint Films and Related Coatings to Fungal Defacement by Accelerated Four-Week Agar Plate Assay

ASTM E84 (2023) Standard Test Method for Surface Burning Characteristics of Building Materials

ASTM E96/E96M (2024) Standard Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials

ASTM E2231 (2021) Standard Practice for Specimen Preparation and Mounting of Pipe and Duct Insulation Materials to Assess Surface Burning Characteristics

CALIFORNIA DEPARTMENT OF PUBLIC HEALTH (CDPH)

CDPH SECTION 01350 (2017; Version 1.2) Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources using Environmental Chambers

FM GLOBAL (FM)

FM APP GUIDE (updated on-line) Approval Guide
<http://www.approvalguide.com/>

GREEN SEAL (GS)

GS-36 (2013) Adhesives for Commercial Use

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 2758 (2014) Paper - Determination of Bursting Strength

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-58 (2018) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation

MIDWEST INSULATION CONTRACTORS ASSOCIATION (MICA)

MICA Insulation Stds (8th Ed) National Commercial & Industrial Insulation Standards

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 90A (2024) Standard for the Installation of Air Conditioning and Ventilating Systems

NFPA 90B (2024) Standard for the Installation of Warm Air Heating and Air Conditioning Systems

NFPA 96 (2024) Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations

SCIENTIFIC CERTIFICATION SYSTEMS (SCS)

SCS SCS Global Services (SCS) Indoor Advantage

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT (SCAQMD)

SCAQMD Rule 1168 (2017) Adhesive and Sealant Applications

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-A-3316 (1987; Rev C; Am 2 1990) Adhesives,
Fire-Resistant, Thermal Insulation

MIL-A-24179 (1969; Rev A; Am 2 1980; Notice 1 1987;
Notice 2 2020) Adhesive, Flexible
Unicellular-Plastic Thermal Insulation

MIL-PRF-19565 (1988; Rev C) Coating Compounds, Thermal
Insulation, Fire- and Water-Resistant,
Vapor-Barrier

UNDERWRITERS LABORATORIES (UL)

UL 94 (2023; Reprint Jan 2024) UL Standard for
Safety Tests for Flammability of Plastic
Materials for Parts in Devices and
Appliances

UL 723 (2020) UL Standard for Safety Test for
Surface Burning Characteristics of
Building Materials

UL 2818 (2022) GREENGUARD Certification Program
For Chemical Emissions For Building
Materials, Finishes And Furnishings

1.2 SYSTEM DESCRIPTION

1.2.1 General

Provide field-applied insulation and accessories on mechanical systems as specified herein; factory-applied insulation is specified under the piping, duct or equipment to be insulated. Furnish and install field applied insulation materials required for use on Government-furnished items as listed in the SPECIAL CONTRACT REQUIREMENTS.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

Submit the three SD types, SD-02 Shop Drawings, SD-03 Product Data, and SD-08 Manufacturer's Instructions at the same time for each system.

SD-02 Shop Drawings

MICA Plates; G

Pipe Insulation Systems and Associated Accessories

Duct Insulation Systems and Associated Accessories

Recycled content for insulation materials; S

SD-03 Product Data

Pipe Insulation Systems; G

Duct Insulation Systems; G

SD-04 Samples

Thermal Insulation; G

Display Samples; G

SD-07 Certificates

Indoor air quality for adhesives; S

SD-08 Manufacturer's Instructions

Pipe Insulation Systems; G

Duct Insulation Systems; G

1.4 CERTIFICATIONS

1.4.1 Adhesives and Sealants

Provide products certified to meet indoor air quality requirements by UL 2818 (Greenguard) Gold, SCS Global Services Indoor Advantage Gold or provide certification or validation by other third-party programs that products meet the requirements of this Section. Provide current product certification documentation from certification body. When product does not have certification, provide validation that product meets the indoor air quality product requirements cited herein.

1.5 QUALITY ASSURANCE

1.5.1 Installer Qualification

Qualified installers will have successfully completed three or more similar type jobs within the last 5 years.

1.6 DELIVERY, STORAGE, AND HANDLING

Deliver materials in the manufacturer's unopened containers. Protect materials delivered and placed in storage from weather, humidity, dirt, dust and other contaminants. The Contracting Officer may reject insulation material and supplies that become dirty, dusty, wet, or contaminated by some other means. Attach manufacturer's stamp or label giving the name of the manufacturer and brand, and a description of the material, date codes, and approximate shelf life (if applicable) to packages or standard containers of insulation, jacket material, cements, adhesives, and coatings delivered for use, and samples required for approval. Insulation packages and containers must be asbestos free.

PART 2 PRODUCTS

2.1 STANDARD PRODUCTS

Provide materials which are the standard products of manufacturers regularly engaged in the manufacture of such products and that essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening. Submit a complete list of materials, including manufacturer's descriptive technical literature, performance data, catalog cuts, and installation instructions. Include the product number, k-value, thickness and furnished accessories including adhesives, sealants and jackets for each mechanical system requiring insulation. The product data must be copyrighted, have an identifying or publication number, and have been published prior to the issuance date of this solicitation. Submit materials furnished under this section together in a booklet.

2.1.1 Insulation System

Provide insulation systems in accordance with the approved MICA National Insulation Standards plates as supplemented by this specification. Provide field-applied insulation for heating, ventilating, and cooling (HVAC) air distribution systems and piping systems that are located within, on, under, and adjacent to buildings; and for plumbing systems. Provide CFC and HCFC free insulation.

2.1.2 Surface Burning Characteristics

Unless otherwise specified, insulation must have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84. Determine flame spread, and smoke developed indexes, by ASTM E84 or UL 723. Test insulation in the same density and installed thickness as the material to be used in the actual construction. Prepare and mount test specimens according to ASTM E2231.

2.2 MATERIALS

Provide insulation that meets or exceed the requirements of ASHRAE 90.2. Ensure insulation exterior is cleanable, grease resistant, non-flaking and non-peeling. Provide compatible materials that do not contribute to corrosion, soften, or otherwise attack surfaces to which applied in either wet or dry state. Use materials on stainless steel surfaces meeting ASTM C795 requirements. Do not use calcium silicate on chilled or cold water systems. Use asbestos free materials. Provide product recognized under UL 94 (if containing plastic) and listed in FM APP GUIDE.

2.2.1 Adhesives

Provide non-aerosol adhesive products used on the interior of the building (defined as inside of the weatherproofing system) that meet either emissions requirements of CDPH SECTION 01350 (limit requirements for either office or classroom spaces regardless of space type) or VOC content requirements of SCAQMD Rule 1168 (HVAC duct sealants must meet limit requirements of "Other" category within SCAQMD Rule 1168 sealants table). Provide aerosol adhesives used on the interior of the building that meet either emissions requirements of CDPH SECTION 01350 (use the office or classroom requirements, regardless of space type) or VOC content requirements of GS-36. Provide certification or validation of indoor air quality for adhesives.

2.2.1.1 Acoustical Lining Insulation Adhesive

Provide a nonflammable, fire-resistant adhesive conforming to ASTM C916, Type I.

2.2.1.2 Mineral Fiber Insulation Cement

Provide cement in accordance with ASTM C195.

2.2.1.3 Lagging Adhesive

Lagging is the material used for thermal insulation, especially around a cylindrical object. This may include the insulation as well as the cloth/material covering the insulation. To resist mold/mildew, use lagging adhesive meeting ASTM D5590 with 0 growth rating. Provide nonflammable and fire-resistant lagging adhesives that have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84. Ensure adhesive is MIL-A-3316, Class 1, pigmented white and suitable for bonding fibrous glass cloth to faced and unfaced fibrous glass insulation board; for bonding cotton brattice cloth to faced and unfaced fibrous glass insulation board; for sealing edges of and bonding glass tape to joints of fibrous glass board; for bonding lagging cloth to thermal insulation; or Class 2 for attaching fibrous glass insulation to metal surfaces. Apply lagging adhesives in strict accordance with the manufacturer's recommendations for pipe and duct insulation.

2.2.1.4 Contact Adhesive

Adhesives may be any of, but not limited to, the neoprene based, rubber based, or elastomeric type that have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84. Ensure adhesive does not adversely affect, initially or in service, the insulation to which it is applied, nor cause any corrosive effect on metal to which it is applied. Ensure that any solvent dispersing medium or volatile component of the adhesive has no objectionable odor and does not contain any benzene or carbon tetrachloride. Ensure dried adhesive does not emit nauseous, irritating, or toxic volatile matters or aerosols when the adhesive is heated to any temperature up to 212 degrees F. The dried adhesive must be nonflammable and fire resistant. Flexible Elastomeric Adhesive: Comply with MIL-A-24179, Type II, Class I. Provide product listed in FM APP GUIDE.

2.2.2 Caulking

ASTM C920, Type S, Grade NS, Class 25, Use A.

2.2.3 Corner Angles

Nominal 0.016 inch aluminum 1 by 1 inch with factory applied kraft backing. Aluminum must be ASTM B209, Alloy 3003, 3105, or 5005.

2.2.4 Fittings

Fabricated Fittings are the prefabricated fittings for flexible elastomeric pipe insulation systems in accordance with ASTM C1710. Together with the flexible elastomeric tubes, they provide complete system integrity for retarding heat gain and controlling condensation drip from chilled-water and refrigeration systems. Flexible elastomeric, fabricated fittings provide thermal protection (0.25 k) and condensation resistance (0.05 Water Vapor Transmission factor). For satisfactory performance, use properly installed protective vapor retarder/barriers and vapor stops on high relative humidity and below ambient temperature applications to reduce movement of moisture through or around the insulation to the colder interior surface.

2.2.5 Finishing Cement

ASTM C450: Mineral fiber hydraulic-setting thermal insulating and finishing cement. All cements that may come in contact with Austenitic stainless steel must comply with ASTM C795.

2.2.6 Fibrous Glass Cloth and Glass Tape

Provide fibrous glass cloth, with 20X20 maximum mesh size, and glass tape with maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84. Provide tape consisting of 4 inch wide rolls. Provide Class 3 tape that is 4.5 ounces/square yard. Elastomeric Foam Tape: Black vapor-retarder foam tape with acrylic adhesive containing an anti-microbial additive.

2.2.7 Staples

Outward clinching type ASTM A167, Type 304 or 316 stainless steel.

2.2.8 Jackets

2.2.8.1 Aluminum Jackets

Provide aluminum jackets consisting of corrugated, embossed or smooth sheet, 0.016 inch nominal thickness; ASTM B209, Temper H14, Temper H16, Alloy 3003, 5005, or 3105. Do not use corrugated aluminum jacket outdoors. Aluminum jacket securing bands must be Type 304 stainless steel, 0.015 inch thick, 1/2 inch wide for pipe under 12 inch diameter and 3/4 inch wide for pipe over 12 inch and larger diameter. Aluminum jacket circumferential seam bands must be 2 by 0.016 inch aluminum matching jacket material. Ensure bands for insulation below ground are 3/4 by 0.020 inch thick stainless steel, or fiberglass reinforced tape. The jacket may, at the option of the Contractor, be provided with a factory fabricated Pittsburgh or "Z" type longitudinal joint. When the "Z" joint is used, use bands at the circumferential joints that are designed by the manufacturer to seal the joints and hold the jacket in

place.

2.2.8.2 Polyvinyl Chloride (PVC) Jackets

Polyvinyl chloride (PVC) jacket and fitting covers must have high impact strength, ultraviolet (UV) resistant rating or treatment and moderate chemical resistance with minimum thickness 0.030 inch.

2.2.8.3 Vapor Barrier/Weatherproofing Jacket

Provide laminated self-adhesive vapor barrier/weatherproofing jacket, greater than 3 plies standard grade, silver, white, black and embossed or greater than 8 ply (minimum 2.9 mils adhesive); with 0.0000 permeability when tested in accordance with ASTM E96/E96M, using the water transmission rate test method; heavy duty, white or natural; and UV resistant. Flexible Elastomeric exterior foam with factory applied, UV Jacket made with a cold weather acrylic adhesive. Construction of laminate designed to provide UV resistance, high puncture, tear resistance and excellent Water Vapor Transmission (WVT) rate.

2.2.8.4 Vapor Barrier/Vapor Retarder

Apply the following criteria to determine which system is required.

- a. On ducts, equip piping and equipment operating below 55 degrees F or located outside with a vapor barrier.
- b. Install ducts, pipes and equipment that are located inside and that always operate above 55 degrees F with a vapor retarder where required as stated in paragraph VAPOR RETARDER REQUIRED.

2.2.9 Vapor Retarder Required

ASTM C921, Type I, minimum puncture resistance 50 Beach units on all surfaces except concealed ductwork, where a minimum puncture resistance of 25 Beach units is acceptable. Minimum tensile strength, 35 pounds/inch width. ASTM C921, Type II, minimum puncture resistance 25 Beach units, tensile strength minimum 20 pounds/inch width. Use jackets on insulation exposed in finished areas that have white finish suitable for painting without sizing. Based on the application, insulation materials that require manufacturer or fabricator applied pipe insulation jackets are cellular glass, when all joints are sealed with a vapor barrier mastic, and mineral fiber. Ensure all non-metallic jackets have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84. Flexible elastomerics require (in addition to vapor barrier skin) vapor retarder jacketing for high relative humidity and below ambient temperature applications.

2.2.9.1 White Vapor Retarder All Service Jacket (ASJ)

ASJ is for use on hot/cold pipes, ducts, or equipment indoors or outdoors if covered by a suitable protective jacket. Provide product which meets all physical property and performance requirements of ASTM C1136, Type I, except a minimum burst strength of 85 psi. ASTM D2863 Limited Oxygen Index (LOI) is a minimum of 31.

In addition, do not use paper or other moisture-sensitive material for the outer exposed surface or the inner-most surface contacting the insulation. Ensure the outer exposed surface is white and has an

emittance no less than 0.80. Ensure the outer exposed surface is paintable.

2.2.9.2 Vapor Retarder/Vapor Barrier Mastic Coatings

2.2.9.2.1 Vapor Barrier

The vapor barrier must be self adhesive (minimum 2 mils adhesive, 3 mils embossed) greater than 3 plies standard grade, silver, white, black and embossed white jacket for use on hot/cold pipes. Ensure permeability is less than 0.02 when tested in accordance with ASTM E96/E96M. Provide products meeting UL 723 or ASTM E84 flame and smoke requirements and that are UV resistant.

2.2.9.2.2 Vapor Retarder

Provide fire and water resistant vapor retarder coating appropriately selected for either outdoor or indoor service. Color must be white. Ensure the water vapor permeance of the compound is in accordance with ASTM C755, Section 7.2.2, Table 2, for insulation type and service conditions. Provide nonflammable, fire resistant coating. To resist mold/mildew, provide coating meeting ASTM D5590 with 0 growth rating. Ensure coating meets MIL-PRF-19565 Type II (if selected for indoor service) and is Qualified Products Database listed. Determine all other application and service properties pursuant to ASTM C647.

2.2.9.3 Laminated Film Vapor Retarder

ASTM C1136, Type I, maximum moisture vapor transmission 0.02 perms, minimum puncture resistance 50 Beach units on all surfaces except concealed ductwork; where Type II, maximum moisture vapor transmission 0.02 perms, a minimum puncture resistance of 25 Beach units is acceptable. Provide vapor retarder with a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84. Flexible Elastomeric exterior foam with factory applied UV Jacket. Construction of laminate designed to provide UV resistance, high puncture, tear resistance and an excellent WVT rate.

2.2.9.4 Polyvinylidene Chloride (PVDC) Film Vapor Retarder

Provide PVDC film vapor retarder with a maximum moisture vapor transmission of 0.02 perms, minimum puncture resistance of 150 Beach units, a minimum tensile strength in any direction of 30 lb/inch when tested in accordance with ASTM D882, and a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84.

2.2.9.5 Polyvinylidene Chloride Vapor Retarder Adhesive Tape

Requirements must meet the same as specified for Laminated Film Vapor Retarder above.

2.2.9.6 Vapor Barrier/Weather Barrier

Ensure the vapor barrier is greater than 3 ply self adhesive laminate -white vapor barrier jacket- superior performance (less than 0.0000 permeability when tested in accordance with ASTM E96/E96M). Provide vapor barrier meeting UL 723 or ASTM E84 25 flame and 50 smoke requirements; and UV resistant. Minimum burst strength 185 psi in accordance with ISO 2758.

Tensile strength 68 lb/inch width (PSTC-1000). Provide tape as specified for laminated film vapor barrier above.

2.2.10 Vapor Retarder Not Required

ASTM C921, Type II, Class D, minimum puncture resistance 50 Beach units on all surfaces except ductwork, where Type IV, maximum moisture vapor transmission 0.10, a minimum puncture resistance of 25 Beach units is acceptable. Provide jacket with a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84.

2.2.11 Wire

Soft annealed ASTM A580/A580M Type 302, 304 or 316 stainless steel, 16 or 18 gauge.

2.2.12 Insulation Bands

Provide 1/2 inch wide; 26 gauge stainless steel insulation bands.

2.2.13 Sealants

Choose sealants from the butyl polymer type, the styrene-butadiene rubber type, or the butyl type of sealants. Provide sealants with a maximum permeance of 0.02 perms based on Procedure B for ASTM E96/E96M, and a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84.

2.3 PIPE INSULATION SYSTEMS

Conform insulation materials to Table 1 and minimum insulation thickness as listed in Table 2 and meet or exceed the requirements of ASHRAE 90.2. Limit pipe insulation materials to those listed herein and meeting the following requirements:

2.3.1 Recycled Materials

Provide insulation materials containing the following minimum percentage of recycled material content by weight:

Rock Wool: 75 percent slag of weight
Fiberglass: 20 percent glass cullet
Rigid Foam: 9 percent recovered material
Phenolic Rigid Foam: 9 percent recovered material

Provide data identifying percentage of recycled content for insulation materials.

2.3.2 Aboveground Cold Pipeline (-30 to 60 deg. F)

Provide insulation for outdoor, indoor, exposed or concealed applications, as follows:

2.3.2.1 Cellular Glass

ASTM C552, Type II, and Type III. Supply the insulation from the fabricator with (paragraph WHITE VAPOR RETARDER ALL SERVICE JACKET (ASJ)) ASJ vapor retarder and installed with all longitudinal overlaps sealed and all circumferential joints ASJ taped or supply the insulation unfaced from

the fabricator and install with all longitudinal and circumferential joints sealed with vapor barrier mastic.

2.3.2.2 Flexible Elastomeric Cellular Insulation

Closed-cell, foam- or expanded-rubber materials containing anti-microbial additive, complying with ASTM C534/C534M, Grade 1, Type I or II. Type I, Grade 1 for tubular materials. Type II, Grade 1, for sheet materials. Ensure Type I and II have vapor retarder/vapor barrier skin on one or both sides of the insulation, and require an additional exterior vapor retarder covering for high relative humidity and below ambient temperature applications.

2.3.2.3 Mineral Fiber Insulation with Integral Wicking Material (MFIWM)

ASTM C547. Install in accordance with manufacturer's instructions. Do not use in applications exposed to outdoor ambient conditions in climatic zones 1 through 4.

2.3.2.4 Polyisocyanurate Insulation

ASTM C591, Type I. Supply the insulation with a factory applied vapor retarder/barrier that complies with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. The insulation and all covering must pass the flame spread index of 25 and the smoke developed index of 50 when tested in accordance with ASTM E84.

2.3.3 Aboveground Hot Pipeline (Above 60 deg. F)

Provide insulation for outdoor, indoor, exposed or concealed applications meeting the following requirements. Supply the insulation with manufacturer's recommended factory-applied jacket/vapor barrier.

2.3.3.1 Mineral Fiber

ASTM C547, Types I, II or III, supply the insulation with manufacturer's recommended factory-applied jacket.

2.3.3.2 Calcium Silicate

ASTM C533, Type I indoor only, or outdoors above 250 degrees F pipe temperature. Supply insulation with the manufacturer's recommended factory-applied jacket/vapor barrier.

2.3.3.3 Cellular Glass

ASTM C552, Type II and Type III. Supply the insulation with manufacturer's recommended factory-applied jacket.

2.3.3.4 Flexible Elastomeric Cellular Insulation

Closed-cell, foam- or expanded-rubber materials containing anti-microbial additive, complying with ASTM C534/C534M, Grade 1, Type I or II to 220 degrees F service. Type I for tubular materials. Type II for sheet materials.

2.3.3.5 Phenolic Insulation

ASTM C1126 Type III to 250 degrees F service must comply with ASTM C795.

Supply the insulation with manufacturer's recommended factory-applied jacket/vapor barrier.

2.3.3.6 Perlite Insulation

ASTM C610

2.3.3.7 Polyisocyanurate Insulation

ASTM C591, Type I. Supply the insulation with a factory applied vapor retarder/barrier that complies with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. The insulation and all covering must pass the flame spread index of 25 and the smoke developed index of 50 when tested in accordance with ASTM E84.

2.3.4 Aboveground Dual Temperature Pipeline

Select insulation for use over a dual temperature pipeline system (Outdoor, Indoor - Exposed or Concealed) in accordance with the most limiting/restrictive case. Find an allowable material from paragraph PIPE INSULATION MATERIALS and determine the required thickness from the most restrictive case. Use the thickness listed in paragraphs INSULATION THICKNESS for cold & hot pipe applications.

2.3.5 Below-ground Pipeline Insulation

For below-ground pipeline insulation, use cellular glass, ASTM C552, type II.

2.4 DUCT INSULATION SYSTEMS

2.4.1 Factory Applied Insulation

Provide factory-applied ASTM C552, cellular glass thermal insulation according to manufacturer's recommendations for insulation with insulation manufacturer's standard reinforced fire-retardant vapor barrier, with identification of installed thermal resistance (R) value and out-of-package R value.

2.4.1.1 Rigid Insulation

Calculate the minimum thickness in accordance with ASHRAE 90.2.

2.4.1.2 Blanket Insulation

Calculate minimum thickness in accordance with ASHRAE 90.2.

2.4.2 Acoustical Duct Lining

2.4.2.1 General

For ductwork indicated or specified in Section 23 30 00 HVAC AIR DISTRIBUTION to be acoustically lined, provide external insulation in accordance with this specification section and in addition to the acoustical duct lining. Do not use acoustical lining in place of duct wrap or rigid board insulation (insulation on the exterior of the duct).

2.4.2.2 Duct Liner

Flexible Elastomeric Acoustical and Conformable Duct Liner Materials:
Flexible Elastomeric Thermal, Acoustical and Conformable Insulation
Compliance with ASTM C534/C534M Grade 1, Type II; and NFPA 90A or NFPA 90B
as applicable.

2.4.3 Duct Insulation Jackets

2.4.3.1 All-Purpose Jacket

Provide insulation with insulation manufacturer's standard reinforced
fire-retardant jacket with or without integral vapor barrier as required
by the service. In exposed locations, provide jacket with a white surface
suitable for field painting.

2.4.3.2 Metal Jackets

2.4.3.2.1 Aluminum Jackets

ASTM B209, Temper H14, minimum thickness of 27 gauge (0.016 inch), with
factory-applied polyethylene and kraft paper moisture barrier on inside
surface. Provide smooth surface jackets for jacket outside dimension 8
inches and larger. Provide corrugated surface jackets for jacket outside
dimension 8 inches and larger. Provide stainless steel bands, minimum
width of 1/2 inch.

2.4.3.2.2 Stainless Steel Jackets

ASTM A167 or ASTM A240/A240M; Type 304, minimum thickness of 33 gauge (0.010 inch), smooth surface with factory-applied polyethylene and kraft
paper moisture barrier on inside surface. Provide stainless steel bands,
minimum width of 1/2 inch.

2.4.3.3 Vapor Barrier/Weatherproofing Jacket

Provide vapor barrier/weatherproofing jacket that is laminated
self-adhesive (minimum 2 mils adhesive, 3 mils embossed) less than 0.0000
permeability, (greater than 3 ply, standard grade, silver, white, black
and embossed or greater than 8 ply (minimum 2.9 mils adhesive), heavy duty
white or natural).

2.4.4 Weatherproof Duct Insulation

Provide ASTM C552, cellular glass thermal insulation , and weatherproofing
as specified in manufacturer's instruction. Multi-ply, Polymeric Blend
Laminate Jacketing: Construction of laminate designed to provide UV
resistance, high puncture, tear resistance and an excellent WVT rate.

PART 3 EXECUTION

3.1 APPLICATION - GENERAL

Apply insulation to unheated and uncooled piping and equipment. Do not
compress flexible elastomeric cellular insulation at joists, studs,
columns, ducts, and hangers. The insulation must not pull apart after a
one hour period; replace any insulation found to pull apart after one hour.

3.1.1 Display Samples

Submit and display, after approval of materials, actual sections of installed systems, properly insulated in accordance with the specification requirements. Such actual sections must remain accessible to inspection throughout the job and will be reviewed from time to time for controlling the quality of the work throughout the construction site. Identify each material used by indicating on an attached sheet the specification requirement for the material and the material by each manufacturer intended to meet the requirement. The Contracting Officer will inspect display sample sections at the jobsite. Keep approved display sample sections on display at the jobsite during the construction period. Upon completion of construction, the display sample sections will be closed and sealed.

3.1.1.1 Pipe Insulation Display Sections

Include as a minimum an elbow or tee, a valve, dielectric waterways and flanges, a hanger with protection shield and insulation insert, or dowel as required, at support point, method of fastening and sealing insulation at longitudinal lap, circumferential lap, butt joints at fittings and on pipe runs, and terminating points for each type of pipe insulation used on the job, and for hot pipelines and cold pipelines, both interior and exterior, even when the same type of insulation is used for these services.

3.1.1.2 Duct Insulation Display Sections

Display sample sections for rigid and flexible duct insulation used on the job. Use a temporary covering to enclose and protect display sections for duct insulation exposed to weather

3.1.2 Installation

Except as otherwise specified, install material in accordance with the manufacturer's written instructions. Do not apply insulation materials until tests and heat tracing specified in other sections of this specification are completed. Remove material such as rust, scale, dirt and moisture from surfaces to receive insulation. Keep insulation clean and dry. Do not remove insulation from its shipping containers until the day it is ready to use and return to like containers or equally protect from dirt and moisture at the end of each workday. Thoroughly clean insulation that becomes dirty prior to use. If insulation becomes wet or if cleaning does not restore the surfaces to like new condition, reject the insulation, and immediately remove from the jobsite. Stagger joints on multi layer insulation. Mix mineral fiber thermal insulating cement with demineralized water when used on stainless steel surfaces. Install insulation, jacketing and accessories in accordance with MICA Insulation Stds plates except where modified herein or on the drawings.

3.1.3 Firestopping

Where pipes and ducts pass through fire walls, fire partitions, above grade floors, and fire rated chase walls, seal the penetration with fire stopping materials as specified in Section 07 84 00 FIRESTOPPING. The protection of ducts at point of passage through firewalls must be in accordance with NFPA 90A and/or NFPA 90B. All other penetrations, such as piping, conduit, and wiring, through firewalls must be protected with a material or system of the same hourly rating that is listed by UL, FM, or

a NRTL.

3.1.4 Painting and Finishing

Paint as specified in Section 09 90 00 PAINTS AND COATINGS.

3.1.5 Installation of Flexible Elastomeric Cellular Insulation

Install flexible elastomeric cellular insulation with seams and joints sealed with rubberized contact adhesive. Do not use flexible elastomeric cellular insulation on surfaces greater than 220 degrees F. Stagger seams when applying multiple layers of insulation. Protect insulation exposed to weather and not shown to have vapor barrier weatherproof jacketing with two coats of UV resistant finish or PVC or metal jacketing as recommended by the manufacturer after the adhesive is dry and cured.

3.1.5.1 Adhesive Application

Apply a brush coating of adhesive to both butt ends to be joined and to both slit surfaces to be sealed. Allow the adhesive to set until dry to touch but tacky under slight pressure before joining the surfaces. Ensure insulation seals at seams and joints are not capable of being pulled apart one hour after application. Replace insulation that can be pulled apart one hour after installation.

3.1.5.2 Adhesive Safety Precautions

Use natural cross-ventilation, local (mechanical) pickup, and/or general area (mechanical) ventilation to prevent an accumulation of solvent vapors, keeping in mind the ventilation pattern must remove any heavier-than-air solvent vapors from lower levels of the workspaces. Gloves and spectacle-type safety glasses are recommended in accordance with safe installation practices.

3.1.6 Welding

Welding is not permitted on piping, duct or without written approval of the Contracting Officer. The capacitor discharge welding process may be used for securing metal fasteners to duct.

3.1.7 Pipes/Ducts/ That Require Insulation

Insulation is required on all pipes, ducts, or except for omitted items as specified.

3.2 PIPE INSULATION SYSTEMS INSTALLATION

3.2.1 Pipe Insulation

3.2.1.1 General

Install pipe insulation on aboveground hot and cold pipeline systems as specified below to form a continuous thermal retarder/barrier, including straight runs, fittings and appurtenances unless specified otherwise. Install full length units of insulation using a single cut piece to complete a run. Do not use cut pieces or scraps abutting each other. Omit pipe insulation on the following:

- a. Pipe used solely for fire protection.
- b. Chromium plated pipe to plumbing fixtures. However, for fixtures used by the physically handicapped, insulate the hot water supply and drain, including the trap, where exposed.
- c. Sanitary drain lines.
- d. Air chambers.
- e. Adjacent insulation.
- f. ASME stamps.
- g. Access plates of fan housings.
- h. Cleanouts or handholes.

3.2.1.2 Pipes Passing Through Walls, Roofs, and Floors

Provide continuous pipe insulation through the sleeve.

Provide an aluminum jacket or vapor barrier/weatherproofing self adhesive jacket (minimum 2 mils adhesive, 3 mils embossed) less than 0.0000 permeability, greater than 3 ply standard grade, silver, white, black and embossed with factory applied moisture retarder over the insulation wherever penetrations require sealing.

3.2.1.2.1 Penetrate Interior Walls

Provide aluminum jacket or vapor barrier/weatherproofing - self adhesive jacket (minimum 2 mils adhesive, 3 mils embossed) less than 0.0000 permeability, greater than 3 plies standard grade, silver, white, black and embossed which extends 2 inches beyond either side of the wall and secure on each end with a band.

3.2.1.2.2 Penetrating Floors

Extend the aluminum jacket from a point below the backup material to a point 10 inches above the floor with one band at the floor and one not more than 1 inch from the end of the aluminum jacket.

3.2.1.2.3 Penetrating Waterproofed Floors

Extend the aluminum jacket rom below the backup material to a point 2 inches above the flashing with a band 1 inch from the end of the aluminum jacket.

3.2.1.2.4 Penetrating Exterior Walls

Continue the aluminum jacket required for pipe exposed to weather through the sleeve to a point 2 inches beyond the interior surface of the wall.

3.2.1.2.5 Penetrating Roofs

Insulate pipe as required for interior service to a point flush with the top of the flashing and sealed with flashing sealant. Tightly butt the insulation for exterior application to the top of flashing and interior insulation. Extend the exterior aluminum jacket 2 inches down beyond the

end of the insulation to form a counter flashing. Seal the flashing and counter flashing underneath with metal jacketing/flashing sealant.

3.2.1.2.6 Hot Water Pipes Supplying Lavatories or Other Similar Heated Service

Terminate the insulation on the backside of the finished wall. Protect the insulation termination with two coats of vapor barrier coating with a minimum total thickness of 1/16 inch applied with glass tape embedded between coats (if applicable). Extend the coating out onto the insulation 2 inches and seal the end of the insulation. Overlap glass tape seams 1 inch. Caulk the annular space between the pipe and wall penetration with approved fire stop material. Cover the pipe and wall penetration with a properly sized (well fitting) escutcheon plate. Ensure the escutcheon plate overlaps the wall penetration at least 3/8 inches.

3.2.1.2.7 Domestic Cold Water Pipes Supplying Lavatories or Other Similar Cooling Service

Terminate the insulation on the finished side of the wall (i.e., insulation must cover the pipe throughout the wall penetration). Protect the insulation with two coats of weather barrier mastic (breather emulsion type weatherproof mastic impermeable to water and permeable to air) with a minimum total thickness of 1/16 inch. Extend the mastic out onto the insulation 2 inches and seal the end of the insulation. Caulk the annular space between the outer surface of the pipe insulation and the wall penetration with an approved fire stop material having vapor retarder properties. Cover the pipe and wall penetration with a properly sized (well fitting) escutcheon plate. Ensure the escutcheon plate overlaps the wall penetration by at least 3/8 inches.

3.2.1.3 Pipes Passing Through Hangers

Ensure insulation, whether hot or cold application, is continuous through hangers. Support all horizontal pipes 2 inches and smaller on hangers with the addition of a Type 40 protection shield to protect the insulation in accordance with MSS SP-58. Whenever insulation shows signs of being compressed, or when the insulation or jacket shows visible signs of distortion at or near the support shield, install insulation inserts as specified below for piping larger than 2 inches, or factory insulated hangers (designed with a load bearing core) can be used.

3.2.1.3.1 Horizontal Pipes Larger Than 2 Inches at 60 Degrees F and Above

Supported on hangers in accordance with MSS SP-58, and Section 22 00 00 PLUMBING, GENERAL PURPOSE.

3.2.1.3.2 Horizontal Pipes Larger Than 2 Inches and Below 60 Degrees F

Supported on hangers with the addition of a Type 40 protection shield in accordance with MSS SP-58. Install an insulation insert of cellular glass, prefabricated insulation pipe hangers, or perlite above 80 degrees F above each shield. Ensure insert covers no less than the bottom 180-degree arc of the pipe. Provide inserts that are the same thickness as the insulation, and extend 2 inches on each end beyond the protection shield. When insulation inserts are required in accordance with the above, and the insulation thickness is less than 1 inch, wooden or cork dowels or blocks may be installed between the pipe and the shield to prevent the weight of the pipe from crushing the insulation, as an option

to installing insulation inserts. Ensure the insulation jacket is continuous over the wooden dowel, wooden block, or insulation insert.

3.2.1.3.3 Vertical Pipes

Supported with either Type 8 or Type 42 riser clamps with the addition of two Type 40 protection shields in accordance with MSS SP-58 covering the 360-degree arc of the insulation. Install an insulation insert of cellular glass or calcium silicate between each shield and the pipe. Ensure the insert covers the 360-degree arc of the pipe. Provide inserts that are the same thickness as the insulation, and extend 2 inches on each end beyond the protection shield. When insulation inserts are required in accordance with the above, and the insulation thickness is less than 1 inch, wooden or cork dowels or blocks may be installed between the pipe and the shield to prevent the hanger from crushing the insulation, as an option instead of installing insulation inserts. Ensure the insulation jacket is continuous over the wooden dowel, wooden block, or insulation insert. Support the vertical weight of the pipe with hangers located in a horizontal section of the pipe. When the pipe riser is longer than 30 feet, support the weight of the pipe additionally with hangers in the vertical run of the pipe that are directly clamped to the pipe, penetrating the pipe insulation. Use insulated hangers and seal the insulation jacket as indicated herein for anchors in a similar service.

3.2.1.3.4 Inserts

Covered with a jacket material of the same appearance and quality as the adjoining pipe insulation jacket, overlap the adjoining pipe jacket 1-1/2 inches, and seal as required for the pipe jacket. Use jacket material to cover inserts in flexible elastomeric cellular insulation conforming to ASTM C1136, Type 1, and is allowed to be of a different material than the adjoining insulation material.

3.2.1.4 Flexible Elastomeric Cellular Pipe Insulation

Use tubular form flexible elastomeric cellular pipe insulation for pipe sizes 6 inches and less. Grade 1, Do not stretch Type II sheet insulation used on pipes larger than 6 inches around the pipe. On pipes larger than 12 inches, adhere the insulation directly to the pipe on the lower 1/3 of the pipe. Stagger seams when applying multiple layers of insulation. Insulate sweat fittings with miter-cut pieces the same size as on adjacent piping. Insulate screwed fittings with sleeved fitting covers fabricated from miter-cut pieces and overlap and seal to the adjacent pipe insulation. Type II requires an additional exterior vapor retarder/barrier covering for high relative humidity and below ambient temperature applications.

3.2.1.5 Pipes in high abuse areas.

In high abuse areas such as janitor closets and traffic areas in equipment rooms, kitchens, and mechanical rooms, utilize stainless steel, aluminum or flexible laminate cladding (comprised of elastomeric, plastic or metal foil laminate) laminated self-adhesive (minimum 2 mils adhesive, 3 mils embossed) vapor barrier/weatherproofing jacket, - less than 0.0000 permeability; (greater than 3 ply, standard grade, silver, white, black and embossed) aluminum jackets. Protect pipe insulation to the 6 foot level. Other areas that specifically require protection to the 6 foot level are .

3.2.1.6 Pipe Insulation Material and Thickness

Pipe insulation materials must be as listed in Table 1 and must meet or exceed the requirements of ASHRAE 90.2.

TABLE 1					
Insulation Material for Piping					
Service					
	Material	Specification	Type	Class	VR/VB Req'd
Chilled Water (Supply & Return, Dual Temperature Piping, 40 F nominal)					
	Cellular Glass	ASTM C552	II	2	Yes
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		Yes
Heating Hot Water Supply & Return, Heated Oil (Max 250 F)					
	Mineral Fiber	ASTM C547	I	1	No
	Calcium Silicate	ASTM C533	I		No
	Cellular Glass	ASTM C552	II	2	No
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Perlite	ASTM C610			No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I	2	No
Cold Domestic Water Piping, Makeup Water & Drinking Fountain Drain Piping					
	Cellular Glass	ASTM C552	II	2	No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
Hot Domestic Water Supply & Recirculating Piping (Max 200 F)					
	Mineral Fiber	ASTM C547	I	1	No
	Cellular Glass	ASTM C552	II	2	No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Faced Phenolic Foam	ASTM C1126	III		Yes
Refrigerant Suction Piping (35 degrees F nominal)					

TABLE 1					
Insulation Material for Piping					
Service					
	Material	Specification	Type	Class	VR/VB Req'd
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Cellular Glass	ASTM C552	II	1	Yes
Compressed Air Discharge, Steam and Condensate Return (201 to 250 Degrees F)					
	Cellular Glass	ASTM C552	II		No
	Mineral Fiber	ASTM C547	I	1	No
	Calcium Silicate	ASTM C533	I		No
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Perlite	ASTM C610			No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I	2	No
Exposed Lavatory Drains, Exposed Domestic Water Piping & Drains to Areas for Handicapped Personnel					
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
Horizontal Roof Drain Leaders (Including Underside of Roof Drain Fittings)					
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Faced Phenolic Foam	ASTM C1126	III		Yes
	Cellular Glass	ASTM C552	III		Yes
Condensate Drain Located Inside Building					
	Cellular Glass	ASTM C552	II	2	No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
Medium Temperature Hot Water, Steam and Condensate (251 to 350 Degrees F)					
	Mineral Fiber	ASTM C547	I	1	No
	Calcium Silicate	ASTM C533	I		No
	Cellular Glass	ASTM C552	I or II		No
	Perlite	ASTM C610			No
	Flexible Elastomeric Cellular	ASTM C534/C534M	I	2	No
High Temperature Hot Water & Steam (351 to 700 Degrees F)					

TABLE 1					
Insulation Material for Piping					
Service					
Material	Specification	Type	Class	VR/VB Req'd	
Mineral Fiber	ASTM C547	I	2	No	
Calcium Silicate	ASTM C533	I		No	
Perlite	ASTM C610			No	
Cellular Glass	ASTM C552			No	
Brine Systems Cryogenics (-30 to 0 Degrees F)					
Cellular Glass	ASTM C552	II	2	No	
Flexible Elastomeric Cellular	ASTM C534/C534M	I		No	
Brine Systems Cryogenics (0 to 34 Degrees F)					
Cellular Glass	ASTM C552	II	2	No	
Flexible Elastomeric Cellular	ASTM C534/C534M	I		No	
Note: VR/VB = Vapor Retarder/Vapor Barrier					

TABLE 2						
Piping Insulation Thickness (inch)						
Do not use integral wicking material in Chilled water applications exposed to outdoor ambient conditions in climatic zones 1 through 4.						
Service						
Material	Tube And Pipe Size (inch)					
	<1	1-<1.5	1.5-<4	4-<8	> or = >8	
Chilled Water (Supply & Return, Dual Temperature Piping, 40 Degrees F nominal)						
Cellular Glass	1.5	2	2	2.5	3	
Mineral Fiber with Wicking Material	1	1.5	1.5	2	2	
Flexible Elastomeric Cellular	1	1	1	N/A	N/A	
Chilled Water (Supply & Return, Dual Temperature Piping, 40 Degrees F nominal)						

TABLE 2						
Piping Insulation Thickness (inch) Do not use integral wicking material in Chilled water applications exposed to outdoor ambient conditions in climatic zones 1 through 4.						
Service						
	Material	Tube And Pipe Size (inch)				
		<1	1-<1.5	1.5-<4	4-<8	> or = >8
	Cellular Glass	1.5	1.5	1.5	1.5	2
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
	Mineral Fiber with Wicking Material	1	1.5	1.5	2	2
Heating Hot Water Supply & Return, Heated Oil (Max 250 F)						
	Mineral Fiber	1.5	1.5	2	2	2
	Calcium Silicate	2.5	2.5	3	3	3
	Cellular Glass	2	2.5	3	3	3
	Perlite	2.5	2.5	3	3	3
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
Cold Domestic Water Piping, Makeup Water & Drinking Fountain Drain Piping						
	Cellular Glass	1.5	1.5	1.5	1.5	1.5
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
Hot Domestic Water Supply & Recirculating Piping (Max 200 F)						
	Mineral Fiber	1	1	1	1.5	1.5
	Cellular Glass	1.5	1.5	1.5	2	2
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
Refrigerant Suction Piping (35 degrees F nominal)						
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
	Cellular Glass	1.5	1.5	1.5	1.5	1.5

TABLE 2						
Piping Insulation Thickness (inch) Do not use integral wicking material in Chilled water applications exposed to outdoor ambient conditions in climatic zones 1 through 4.						
Service						
	Material	Tube And Pipe Size (inch)				
		<1	1-<1.5	1.5-<4	4-<8	> or = >8
Compressed Air Discharge, Steam and Condensate Return (201 to 250 Degrees F)						
	Mineral Fiber	1.5	1.5	2	2	2
		1.5*	2*	2.5*	3*	3.5*
	Calcium Silicate	2.5	3	4	4	4.5
	Cellular Glass	2	2.5	3	3	3
	Perlite	2.5	3	4	4	4.5
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
Exposed Lavatory Drains, Exposed Domestic Water Piping & Drains to Areas for Handicapped Personnel						
	Flexible Elastomeric Cellular	0.5	0.5	0.5	0.5	0.5
Horizontal Roof Drain Leaders (Including Underside of Roof Drain Fittings)						
	Cellular Glass	1.5	1.5	1.5	1.5	1.5
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
	Faced Phenolic Foam	1	1	1	1	1
Condensate Drain Located Inside Building						
	Cellular Glass	1.5	1.5	1.5	1.5	1.5
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
Medium Temperature Hot Water, Steam and Condensate (251 to 350 Degrees F)						
	Mineral Fiber	1.5	3	3	4	4
		2.5*	*	3.5*		

TABLE 2						
Piping Insulation Thickness (inch) Do not use integral wicking material in Chilled water applications exposed to outdoor ambient conditions in climatic zones 1 through 4.						
Service						
	Material	Tube And Pipe Size (inch)				
		<1	1-<1.5	1.5-<4	4-<8	> or = >8
	Calcium Silicate	2.5	3.5	4.5	4.5	5
	Perlite	2.5	3.5	4.5	4.5	5
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
High Temperature Hot Water & Steam (351 to 700 Degrees F)						
	Mineral Fiber	2.5	3	3	4	4
	Calcium Silicate	4	4.5	6	6	6
	Perlite	4	4.5	6	6	6
Brine Systems Cryogenics (-30 to 0 Degrees F)						
	Cellular Glass	2.5	2.5	3	3	3.5
	Flexible Elastomeric Cellular	1	1	N/A	N/A	N/A
Brine Systems Cryogenics (0 to 34 Degrees F)						
	Cellular Glass	2	2	2	2.5	3
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A

3.2.2 Aboveground Cold Pipelines

Insulate the following cold pipelines for minus 30 to plus 60 degrees F in accordance with Table 2 except those piping listed in subparagraph Pipe Insulation in PART 3 as to be omitted. This includes but is not limited to the following:

- a. Make-up water.
- b. Horizontal and vertical portions of interior roof drains.
- c. Refrigerant suction lines.

- d. Chilled water.
- e. Dual temperature water, i.e. HVAC hot/chilled water.
- f. Air conditioner condensate drains.
- g. Brine system cryogenics
- h. Exposed lavatory drains and domestic water lines serving plumbing fixtures for handicap persons.
- i. Domestic cold and chilled drinking water.

3.2.2.1 Insulation Material and Thickness

Determine insulation thickness for cold pipelines using Table 2.

3.2.2.2 Factory or Field applied Jacket

Cover insulation with a factory applied vapor retarder jacket/vapor barrier or field applied seal welded PVC jacket or greater than 3 ply laminated self-adhesive (minimum 2 mils adhesive, 3 mils embossed) vapor barrier/weatherproofing jacket - less than 0.0000 permeability, standard grade, silver, white, black and embossed for use with Mineral Fiber, Cellular Glass, and Phenolic Foam Insulated Pipe. For insulation inside the building, to be protected with an aluminum jacket or greater than 3 ply vapor barrier/weatherproofing self-adhesive (minimum 2 mils adhesive, 3 mils embossed) product, less than 0.0000 permeability, standard grade, Embossed Silver, White & Black, install the insulation and vapor retarder jacket as specified herein. Install the aluminum jacket or greater than 3 ply vapor barrier/weatherproofing self-adhesive (minimum 2 mils adhesive, 3 mils embossed) product, less than 0.0000 permeability, standard grade, embossed silver, White & Black, as specified for piping exposed to weather, except sealing of the laps of the aluminum jacket is not required. In high abuse areas such as janitor closets and traffic areas in equipment rooms, kitchens, and mechanical rooms, provide aluminum jackets or greater than 3 ply vapor barrier/weatherproofing self-adhesive (minimum 2 mils adhesive, 3 mils embossed) product, less than 0.0000 permeability, standard grade, embossed silver, white & black, for pipe insulation to the 6 ft level. Other areas that specifically require protection to the 6 ft level are .

3.2.2.3 Installing Insulation for Straight Runs Hot and Cold Pipe

Apply insulation to the pipe with tight butt joints. Seal all butted joints and ends with joint sealant and seal with a vapor retarder coating, greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape or PVDC adhesive tape.

3.2.2.3.1 Longitudinal Laps of the Jacket Material

Overlap not less than 1-1/2 inches. Provide butt strips 3 inches wide for circumferential joints.

3.2.2.3.2 Laps and Butt Strips

Secure with adhesive and staple on 4 inch centers if not factory self-sealing. If staples are used, seal in accordance with paragraph STAPLES below. Note that staples are not required with cellular glass

systems.

3.2.2.3.3 Factory Self-Sealing Lap Systems

May be used when the ambient temperature is between 40 and 120 degrees F during installation. Install the lap system in accordance with manufacturer's recommendations. Use a stapler only if specifically recommended by the manufacturer. Where gaps occur, replace the section or repair the gap by applying adhesive under the lap and then stapling.

3.2.2.3.4 Staples

Coat all staples, including those used to repair factory self-seal lap systems, with a vapor retarder coating or PVDC adhesive tape or greater than 3 ply laminate jacket - 0.0000 perm adhesive tape. Coat all seams, except those on factory self-seal systems, with vapor retarder coating or PVDC adhesive tape or greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape.

3.2.2.3.5 Breaks and Punctures in the Jacket Material

Patch by wrapping a strip of jacket material around the pipe and secure it with adhesive, staple, and coat with vapor retarder coating or PVDC adhesive tape or greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape. Extend the patch not less than 1-1/2 inches past the break.

3.2.2.3.6 Penetrations Such as Thermometers

Fill the voids in the insulation and seal with vapor retarder coating or PVDC adhesive tape or greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape.

3.2.2.3.7 Flexible Elastomeric Cellular Pipe Insulation

Install by slitting the tubular sections and applying them onto the piping or tubing. Alternately, whenever possible slide un-slit sections over the open ends of piping or tubing. Secure all seams and butt joints and seal with adhesive. When using self seal products, secure only the butt joints with adhesive. Push insulation on the pipe, never pulled. Stretching of insulation may result in open seams and joints. Clean cut all edges. Rough or jagged edges of the insulation are not be permitted. Use proper tools such as sharp knives. Do not stretch Grade 1, Type II sheet insulation around the pipe when used on pipe larger than 6 inches. On pipes larger than 12 inches, adhere sheet insulation directly to the pipe on the lower 1/3 of the pipe.

3.2.2.4 Insulation for Fittings and Accessories

- a. Butt pipe insulation tightly to the insulation of the fittings and accessories. Seal the butted joints and ends with joint sealant and seal with a vapor retarder coating or PVDC adhesive tape or greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape.
- b. Place precut or preformed insulation around all fittings and accessories and conform to MICA plates except as modified herein: 5 for anchors; 10, 11, and 13 for fittings; 14 for valves; and 17 for flanges and unions. Insulation must be the same insulation as the pipe insulation, including same density, thickness, and thermal

conductivity. Where precut/preformed is unavailable, rigid preformed pipe insulation sections may be segmented into the shape required. Use insulation of the same thickness and conductivity as the adjoining pipe insulation. If nesting size insulation is used, overlap the insulation 2 inches or one pipe diameter. Elbows insulated using segments must conform to MICA Tables 12.20 "Mitered Insulation Elbow". Submit a booklet containing completed MICA Insulation Stds plates detailing each insulating system for each pipe, duct, insulating system, after approval of materials and prior to applying insulation.

- (1) Ensure MICA plates detail the materials to be installed and the specific insulation application. Submit all MICA plates required showing the entire insulating system, including plates required to show insulation penetrations, vessel bottom and top heads, legs, and skirt insulation as applicable. Present all variations of insulation systems including locations, materials, vaporproofing, jackets and insulation accessories.
 - (2) If the Contractor elects to submit detailed drawings instead of edited MICA Plates, ensure the detail drawings are technically equivalent to the edited MICA Plate submittal.
- c. Upon completion of insulation installation on flanges, unions, valves, anchors, fittings and accessories, terminations, seams, joints and insulation not protected by factory vapor retarder jackets or PVC fitting covers must be protected with PVDC or greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape or two coats of vapor retarder coating with a minimum total thickness of 1/16 inch, applied with glass tape embedded between coats. Overlap tap seams 1 inch. Extend the coating out onto the adjoining pipe insulation 2 inches. Protect fabricated insulation with a factory vapor retarder jacket with either greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape, standard grade, silver, white, black and embossed or PVDC adhesive tape or two coats of vapor retarder coating with a minimum thickness of 1/16 inch and with a 2 inch wide glass tape embedded between coats. Where fitting insulation butts to pipe insulation, seal the joints with a vapor retarder coating and a 4 inch wide ASJ tape which matches the jacket of the pipe insulation.
- d. Insulate anchors attached directly to the pipe for a sufficient distance to prevent condensation but no less than 6 inches from the insulation surface.
- e. Mark insulation to show the location of unions, strainers, and check valves.

3.2.2.5 Optional PVC Fitting Covers

At the option of the Contractor, premolded, one or two piece PVC fitting covers may be used in lieu of the vapor retarder and embedded glass tape. Use factory precut or premolded insulation segments under the fitting covers for elbows. Use insulation segments which are the same insulation as the pipe insulation including same density, thickness, and thermal conductivity. Secure the covers by PVC vapor retarder tape, adhesive, seal welding or with tacks made for securing PVC covers. Seal seams in the cover, and tacks and laps to adjoining pipe insulation jacket, with vapor retarder tape to ensure that the assembly has a continuous vapor seal.

3.2.3 Aboveground Hot Pipelines

3.2.3.1 General Requirements

Insulate all hot pipe lines above 60 degrees F, except those piping listed in subparagraph Pipe Insulation in PART 3 as to be omitted, in accordance with Table 2. This includes but is not limited to the following:

- a. Domestic hot water supply & re-circulating system.
- b. Steam.
- c. Condensate & compressed air discharge.
- d. Hot water heating.
- e. Heated oil.
- f. Water defrost lines in refrigerated rooms.

Cover insulation, in accordance with manufacturer's recommendations, with a factory applied Type I jacket or field applied aluminum where required or seal welded PVC.

3.2.3.2 Insulation for Fittings and Accessories

Butt pipe insulation tightly to the insulation of the fittings and accessories. Seal butted joints and ends with joint sealant. Mark insulation to show the location of unions, strainers, check valves and other components that would otherwise be hidden from view by the insulation.

3.2.3.2.1 Precut or Preformed

Place precut or preformed insulation around all fittings and accessories. Use the same insulation as the pipe insulation, including same density, thickness, and thermal conductivity.

3.2.3.2.2 Rigid Preformed

Where precut/preformed is unavailable, rigid preformed pipe insulation sections may be segmented into the shape required. Use insulation that is the same thickness and conductivity as the adjoining pipe insulation. If nesting size insulation is used, do not overlap insulation 2 inches or one pipe diameter. Elbows insulated using segments must conform to MICA Tables 12.20 "Mitered Insulation Elbow".

3.2.4 Piping Exposed to Weather

Insulate and jacket piping exposed to weather as specified for the applicable service inside the building. After this procedure, apply a laminated self-adhesive (minimum 2 mils adhesive, 3 mils embossed) vapor barrier/weatherproofing jacket - less than 0.0000 permeability (greater than 3 ply, standard grade, silver, white, black and embossed aluminum jacket, stainless steel or PVC jacket).

PVC jacketing requires no factory-applied jacket beneath it, however apply an all service jacket if factory applied jacketing is not furnished.

Treat flexible elastomeric cellular insulation exposed to weather in accordance with paragraph INSTALLATION OF FLEXIBLE ELASTOMERIC CELLULAR INSULATION in PART 3.

3.2.4.1 Aluminum Jacket

The jacket for hot piping may be factory applied. Overlap the jacket no less than 2 inches at longitudinal and circumferential joints and secure with bands at no more than 12 inch centers. Overlap longitudinal joints down to shed water and locate at 4 or 8 o'clock positions. Seal joints on piping 60 degrees F and below with metal jacketing/flashing sealant while overlapping to prevent moisture penetration. Where jacketing on piping 60 degrees F and below abuts an un-insulated surface, caulk joints to prevent moisture penetration. Seal joints on piping above 60 degrees F with a moisture retarder.

3.2.4.2 Insulation for Fittings

Insulate and finish flanges, unions, valves, fittings, and accessories as specified for the applicable service. Apply two coats of breather emulsion type weatherproof mastic (impermeable to water, permeable to air) recommended by the insulation manufacturer with glass tape embedded between coats. Overlap tap no less than 1 inch and the adjoining aluminum jacket no less than 2 inches. Factory preformed aluminum jackets may be used in lieu of the above. Provide molded PVC fitting covers when PVC jackets are used for straight runs of pipe. Provide PVC fitting covers that have adhesive welded joints and are weatherproof laminated self-adhesive (minimum 2 mils adhesive, 3 mils embossed) vapor barrier/weatherproofing jacket - less than 0.0000 permeability, (greater than 3 ply, standard grade, silver, white, black and embossed, and UV resistant).

3.2.4.3 PVC Jacket

Provide ultraviolet resistant PVC jacket that is adhesive welded weather tight with manufacturer's recommended adhesive. Include provision for thermal expansion.

3.2.4.4 Stainless Steel Jackets

ASTM A167 or ASTM A240/A240M; Type 304, minimum thickness of 33 gauge (0.010 inch), smooth surface with factory-applied polyethylene and kraft paper moisture barrier on inside surface. Provide stainless steel bands, minimum width of 1/2 inch.

3.2.5 Below Ground Pipe Insulation

Insulate below ground pipes in accordance with Table 2, except as precluded in subparagraph Pipe Insulation in PART 3. This includes, but is not limited to the following:

- a. Heated oil.
- b. Domestic hot water.
- c. Heating hot water.
- d. Dual temperature water.

- e. Steam.
- f. Condensate.

3.2.5.1 Type of Insulation

Insulate below ground pipe with Cellular Glass insulation, in accordance with manufacturer's instructions for application with thickness as determined from Table 2 (whichever is the most restrictive).

3.2.5.2 Installation of Below ground Pipe Insulation

- a. Coat bore surfaces of the insulation with a thin coat of gypsum cement of a type recommended by the insulation manufacturer. Ensure coating thickness is sufficient to fill surface cells of insulation. Do not use mastic type materials for this coating. Note that unless this is for a cyclic application (i.e., one that fluctuates between high and low temperature on a daily process basis) there is no need to bore coat the material.
- b. Use stainless steel bands, 3/4 inch wide by 0.020 inch thick to secure insulation in place. Apply a minimum of two bands per section of insulation. As an alternate, fiberglass reinforced tape may be used to secure insulation on piping up to 12 inches in diameter. Apply a minimum of two bands per section of insulation.
- c. Terminate insulation at anchor blocks but continue through sleeves and manholes.
- d. At point of entry to buildings, terminate underground insulation 2 inches inside the wall or floor, butt tightly against the aboveground insulation and seal the butt joint with high temperature silicone sealant and cover with fibrous glass tape.
- e. Make provision for expansion and contraction of the insulation system in accordance with the insulation manufacturer's recommendations.
- f. Insulate flanges, couplings, valves, and fittings with factory pre-molded, prefabricated, or field-fabricated sections of insulation of the same material and thickness as the adjoining pipe insulation. Secure insulation sections as recommended by the manufacturer.
- g. Finish insulation, including fittings, with three coats of asphaltic mastic, with 6 by 5.5 mesh synthetic reinforcing fabric embedded between coats. Overlap fabric a minimum of 2 inches at joints. Ensure total film thickness is a minimum of 3/16 inch. As an alternate, apply a prefabricated bituminous laminated jacket, reinforced with internal reinforcement mesh, to the insulation. Use jacketing material and application procedures that match manufacturer's written instructions. Vapor barrier - less than 0.0000 permeability self adhesive (minimum 2 mils adhesive, 3 mils embossed) jacket greater than 3 ply, standard grade, silver, white, black and embossed or greater than 8 ply (minimum 2.9 mils adhesive), heavy duty, white or natural). Use application procedures that match the manufacturer's written instructions.
- h. At termination points, other than building entrances, use mastic and cloth or tape to cover the ends of insulation and extend 2 inches along the bare pipe.

3.3 DUCT INSULATION SYSTEMS INSTALLATION

Except for oven hood exhaust duct insulation, install corner angles on external corners of insulation on ductwork in exposed finished spaces before covering with jacket. Air conditioned spaces are defined as those spaces directly supplied with cooled conditioned air (or provided with a cooling device such as a fan-coil unit) and heated conditioned air (or provided with a heating device such as a unit heater, radiator or convector).

3.3.1 Duct Insulation Minimum Thickness

Duct insulation minimum thickness in accordance with Table 4.

Cold Air Ducts	2.0
Relief Ducts	1.5
Fresh Air Intake Ducts	1.5
Warm Air Ducts	2.0
Relief Ducts	1.5
Fresh Air Intake Ducts	1.5

3.3.2 Insulation and Vapor Retarder/Vapor Barrier for Cold Air Duct

Provide insulation and vapor retarder/vapor barrier for the following cold air ducts and associated equipment.

- a. Supply ducts.
- b. Return air ducts.
- c. Relief ducts.
- d. Flexible run-outs (field-insulated).
- e. Plenums.
- f. Duct-mounted coil casings.
- g. Coil headers and return bends.
- h. Coil casings.
- i. Fresh air intake ducts.
- j. Filter boxes.
- k. Mixing boxes (field-insulated).

- l. Supply fans (field-insulated).
- m. Site-erected air conditioner casings.
- n. Ducts exposed to weather.
- o. Combustion air intake ducts.

Use insulation for rectangular ducts that is flexible type where concealed, minimum density 3/4 pcf, and rigid type where exposed, minimum density 3 pcf. Provide insulation for both concealed or exposed round/oval ducts that is flexible type, minimum density 3/4 pcf or a semi rigid board, minimum density 3 pcf, formed or fabricated to a tight fit, edges beveled and joints tightly butted and staggered. Provide insulation for all exposed ducts with either a white, paint-able, factory-applied Type I jacket or a field applied vapor retarder/vapor barrier jacket coating finish as specified. Ensure the total field applied dry film thickness is approximately 1/16 inch. Provide insulation on all concealed duct with a factory-applied Type I or II vapor retarder/vapor barrier jacket. Continue duct insulation through sleeves and prepare openings except firewall penetrations. Duct insulation terminating at fire dampers, must be continuous over the damper collar and retaining angle of fire dampers, which are exposed to unconditioned air and which may be prone to condensate formation. Provide duct insulation and vapor retarder/vapor barrier to cover the collar, neck, and un-insulated surfaces of diffusers, registers and grills. Apply vapor retarder/vapor barrier materials to form a complete unbroken vapor seal over the insulation. Seal sheet metal duct in accordance with Section 23 30 00 HVAC AIR DISTRIBUTION.

3.3.2.1 Installation on Concealed Duct

- a. For rectangular, oval or round ducts, attach flexible insulation by applying adhesive around the entire perimeter of the duct in 6 inch wide strips on 12 inch centers.
- b. For rectangular and oval ducts, 24 inches and larger, additionally secure insulation to bottom of ducts using mechanical fasteners. Space fasteners on 16 inch centers and no more than 16 inches from duct corners.
- c. For rectangular, oval and round ducts, provide mechanical fasteners on sides of duct risers for all duct sizes. Space fasteners on 16 inch centers and no more than 16 inches from duct corners.
- d. Impale insulation on the mechanical fasteners (self stick pins) where used and press thoroughly into the adhesive. Take care to ensure vapor retarder/vapor barrier jacket joints overlap 2 inches. Do not compress insulation to a thickness less than that specified. Carry insulation over standing seams and trapeze-type duct hangers.
- e. Where mechanical fasteners are used, install self-locking washers and trim and bend the pin over.
- f. Secure jacket overlaps with staples and tape as necessary to ensure a secure seal. Coat staples, tape and seams with a brush coat of vapor retarder coating or PVDC adhesive tape or greater than 3 ply laminate (minimum 2 mils adhesive, 3 mils embossed) - less than 0.0000 perm adhesive tape.

- g. Cover breaks in the jacket material with patches of the same material as the vapor retarder jacket. Do not extend patches less than 2 inches beyond the break or penetration in all directions and secure with tape and staples. Seal staples and tape joints with a brush coat of vapor retarder coating or PVDC adhesive tape or greater than 3 ply laminate (minimum 2 mils adhesive, 3 mils embossed) - less than 0.0000 perm adhesive tape.
- h. At jacket penetrations such as hangers, thermometers, and damper operating rods, fill voids in the insulation and seal the penetration with a brush coat of vapor retarder coating or PVDC adhesive tape greater than 3 ply laminate (minimum 2 mils adhesive, 3 mils embossed) - less than 0.0000 perm adhesive tape.
- i. Seal insulation terminations and pin punctures and flash with a reinforced vapor retarder coating finish or tape with a brush coat of vapor retarder coating.. Ensure the coating overlaps the adjoining insulation and un-insulated surface 2 inches. Extend pin puncture coatings 2 inches from the puncture in all directions.
- j. Where insulation standoff brackets occur, extend insulation under the bracket and terminate the jacket at the bracket.

3.3.2.2 Installation on Exposed Duct Work

- a. For rectangular ducts, secure rigid insulation to the duct by mechanical fasteners on all four sides of the duct, space no more than 12 inches apart and no more than 3 inches from the edges of the insulation joints. Provide a minimum of two rows of fasteners for each side of duct 12 inches and larger. Provide one row for each side of duct less than 12 inches. Provide mechanical fasteners that are corrosion resistant as G60 coated galvanized steel, and indefinitely sustain a 50 lb tensile dead load test perpendicular to the duct wall.
- b. Form duct insulation with minimum jacket seams. Fasten each piece of rigid insulation to the duct using mechanical fasteners. When the height of projections is less than the insulation thickness, bring insulation up to standing seams, reinforcing, and other vertical projections and do not carry over. Continue vapor retarder/barrier jacket across seams, reinforcing, and projections. When height of projections is greater than the insulation thickness, carry over insulation and jacket. Apply insulation with joints tightly butted. Neatly bevel insulation around name plates and access plates and doors.
- c. Impale insulation on the fasteners; install self-locking washers and trim and bend the pin over.
- d. Seal joints in the insulation jacket with a 4 inch wide strip of tape. Seal taped seams with a brush coat of vapor retarder coating.
- e. Cover breaks and ribs or standing seam penetrations in the jacket material with a patch of the same material as the jacket. Do not extend patches less than 2 inches beyond the break or penetration and secure with tape and staple. Seal staples and joints with a brush coat of vapor retarder coating.
- f. At jacket penetrations such as hangers, thermometers, and damper operating rods, fill the voids in the insulation and seal the

penetrations with a flashing sealant.

- g. Seal and flash insulation terminations and pin punctures with a reinforced vapor retarder coating finish. Ensure coating overlaps the adjoining insulation and un-insulated surface 2 inches. Extend pin puncture coatings 2 inches from the puncture in all directions.
- h. Insulate oval and round ducts, flexible type, with factory Type I jacket insulation with minimum density of 3/4 pcf, attach in accordance with MICA standards.

3.3.3 Insulation for Warm Air Duct

Provide insulation and vapor barrier for the following warm air ducts and associated equipment:.

- a. Supply ducts.
- b. Return air ducts.
- c. Relief air ducts
- d. Flexible run-outs (field insulated).
- e. Plenums.
- f. Duct-mounted coil casings.
- g. Coil-headers and return bends.
- h. Coil casings.
- i. Fresh air intake ducts.
- j. Filter boxes.
- k. Mixing boxes.
- l. Supply fans.
- m. Site-erected air conditioner casings.
- n. Ducts exposed to weather.
- o. Exhaust ducts passing through concealed spaces exhausting conditioned air.

Provide insulation for rectangular ducts that is flexible type where concealed, and rigid type where exposed. Provide insulation on exposed ducts with a white, paint-able, factory-applied Type II jacket, or finish with adhesive finish. Use flexible type insulation for round ducts, with a factory-applied Type II jacket. Provide insulation on concealed duct with a factory-applied Type II jacket. Accomplish adhesive finish where indicated to be used by applying two coats of adhesive with a layer of glass cloth embedded between the coats. Ensure total dry film thickness is approximately 1/16 inch. Continue duct insulation through sleeves and prepare openings. Terminate duct insulation at fire dampers and flexible connections.

3.3.3.1 Installation on Concealed Duct

- a. For rectangular, oval and round ducts, attach insulation by applying adhesive around the entire perimeter of the duct in 6 inch wide strips on 12 inch centers.
- b. For rectangular and oval ducts 24 inches and larger, secure insulation to the bottom of ducts using mechanical fasteners. Space fasteners on 18 inch centers and no more than 18 inches from duct corner.
- c. For rectangular, oval and round ducts, provide mechanical fasteners on sides of duct risers for all duct sizes. Space fasteners on 18 inch centers and no more than 18 inches from duct corners.
- d. Impale insulation on the mechanical fasteners where used. Do not compress insulation to a thickness less than that specified. Carry insulation over standing seams and trapeze-type hangers.
- e. Install self-locking washers where mechanical fasteners are used and trim and bend the pin over.
- f. Do not overlap insulation jacket less than 2 inches at joints and secure the lap and staple on 4 inch centers.

3.3.3.2 Installation on Exposed Duct

- a. For rectangular ducts, secure the rigid insulation to the duct using mechanical fasteners on all four sides of the duct, space no more than 16 inches apart and no more than 6 inches from the edges of the insulation joints. Provide a minimum of two rows of fasteners for each side of duct 12 inches and larger and a minimum of one row for each side of duct less than 12 inches.
- b. Form duct insulation with factory-applied jacket with minimum jacket seams, and fasten each piece of rigid insulation to the duct using mechanical fasteners. When the height of projection is less than the insulation thickness, bring insulation up to standing seams, reinforcing, and other vertical projections and do not carry over the projection. Continue jacket across seams, reinforcing, and projections. Where the height of projections is greater than the insulation thickness, carry insulation and jacket over the projection.
- c. Impale insulation on the fasteners; install self-locking washers and trim and bend the pin over.
- d. Seal joints on jacketed insulation with a 4 inch wide strip of tape and brush with vapor retarder coating.
- e. Cover breaks and penetrations in the jacket material with a patch of the same material as the jacket. Extend patches no less than 2 inches beyond the break or penetration and secure with adhesive and staple.
- f. Seal insulation terminations and pin punctures with tape and brush with vapor retarder coating.
- g. Insulate oval and round ducts, flexible type, with factory Type I jacket insulation, minimum density of 3/4 pcf attach by staples spaced no more than 16 inches and no more than 6 inches from the degrees of joints. Seal joints in accordance with item "d." above.

3.3.4 Ducts Handling Air for Dual Purpose

For air handling ducts for dual purpose below and above 60 degrees F, insulate ducts as specified for cold air duct.

3.3.5 Insulation for Evaporative Cooling Duct

Insulate evaporative cooling supply duct located in spaces not evaporatively cooled. Use material and installation requirements as specified for duct insulation for warm air duct.

3.3.6 Duct Test Holes

After duct systems have been tested, adjusted, and balanced, repair breaks in the insulation and jacket in accordance with the applicable section of this specification for the type of duct insulation to be repaired.

3.3.7 Duct Exposed to Weather

3.3.7.1 Installation

Insulate and finish ducts exposed to weather as specified for the applicable service for exposed duct inside the building. After the above is accomplished, further finish the insulation as detailed in the following subparagraphs.

3.3.7.2 Round Duct

Laminated self-adhesive (minimum 2 mils adhesive, 3 mils embossed) vapor barrier/weatherproofing jacket - Less than 0.0000 permeability, (greater than 3 ply, standard grade, silver, white, black and embossed or greater than 8 ply, heavy duty, white and natural) membrane must be applied overlapping material by 3 inches no bands or caulking needed - see manufacturer's recommended installation instructions. Aluminum jacket with factory applied moisture retarder must be applied with the joints lapped no less than 3 inches and secured with bands located at circumferential laps and at no more than 12 inch intervals throughout. Lap horizontal joints down to shed water and located at 4 or 8 o'clock position. Seal joints with metal jacketing sealant to prevent moisture penetration. Where jacketing abuts an un-insulated surface, seal joints with metal jacketing sealant.

3.3.7.3 Fittings

Finish fittings and other irregular shapes as specified for rectangular ducts.

3.3.7.4 Rectangular Ducts

Apply two coats of weather barrier mastic reinforced with fabric or mesh for outdoor application to the entire surface. Ensure each coat of weatherproof mastic has a minimum thickness of 1/16 inch. Ensure exterior is a metal jacketing applied for mechanical abuse and weather protection, and secure with screws or vapor barrier/weatherproofing jacket less than 0.0000 permeability greater than 3 ply, standard grade, silver, white, black, and embossed or greater than 8 ply, heavy duty white and natural. Apply membrane overlapping material by 3 inches. No bands or caulking needed-see manufacturing recommend installation instructions.

3.3.8 Kitchen Exhaust Duct Insulation

NFPA 96 for . Provide insulation with 3/4 inch wide, minimum 0.15 inch thick galvanized steel bands spaced not over 12 inches o.c.; or 16 gauge galvanized steel wire with corner clips under the wire; or with heavy welded pins spaced not over 12 inches apart each way. Do not use adhesives.

-- End of Section --

SECTION 23 08 00.00 20

COMMISSIONING OF MECHANICAL AND PLUMBING SYSTEMS
02/21, CHG 1: 05/21

PART 1 GENERAL

Total Building Commissioning (TBCx) is a systematic, quality-focused process for enhancing the delivery of a project that focuses on verifying and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the project requirements. The purpose is to reduce the cost and performance risks associated with delivering facilities projects, and to increase value to owners, occupants, and users.

1.1 DEFINITIONS

Commissioning Process (Cx) - a quality-focused process for enhancing the delivery of a project. Refer to ASHRAE 202 for a comprehensive description of the commissioning process.

Commissioning Provider (CxP)- The entity who leads, plans, and coordinates the Commissioning Team. The terms Commissioning Provider, Commissioning Firm, Lead Commissioning Specialist, Commissioning Specialist, and Commissioning Authority (CA or CxA) when used by sustainable Third Party Certification (TPC) programs, are interchangeable.

Commissioning Authority - The Government retains the authority for oversight and assurance of the entire commissioning process, and final approval of all commissioning deliverables.

1.2 SEQUENCING AND SCHEDULING

Complete the following prior to starting Functional Performance Tests of mechanical systems:

- a. All equipment and systems completed, cleaned, flushed, disinfected, calibrated, tested, and operate in accordance with contract documents and construction plans and specifications
- b. Final DALI Report submitted and approved in accordance with Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC
- d. The Certificate of Readiness submitted and approved in accordance with Section TOTAL BUILDING COMMISSIONING
- e. Pre-final Testing, Adjusting, and Balancing Report submitted in accordance with Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section

01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Test Equipment; G

SD-06 Test Reports

Pipe Flushing, Testing, And Water Treatment Reports; G

Full-Load Test Report; G1.4 ACCESSIBILITY REQUIREMENTS

Equipment, systems, and devices for commissioned systems must be accessible. Make necessary modifications if systems and devices are not accessible for inspections and testing.

Assist commissioning team in testing by removing equipment covers, opening access panels, and other required activities that assist with visual oversight. Furnish ladders, flashlights, meters, gauges, or other inspection equipment as necessary.

1.5 COORDINATION

Refer to Section TOTAL BUILDING COMMISSIONING for requirements pertaining to coordination during the commissioning process. Coordinate with the Commissioning Provider in accordance with Section and in accordance with the Commissioning Plan to schedule inspections as required to support the commissioning process. Furnish additional information requested by the Commissioning Provider. Coordinate scheduling of Functional Performance Testing with the commissioning team. Upload plans, reports, notes, and other documentation to the Commissioning Provider's web-based commissioning software, or as specified in the commissioning plan, as it is completed.

1.6 PIPE FLUSHING, TESTING, AND WATER TREATMENT REPORTS

Test requirements are specified in Division 22 and 23 piping Sections. Prepare a pipe system cleaning, flushing, and hydrostatic testing log. Provide cleaning, flushing, testing, and water treatment log and final reports.

Include the following in the pipe system cleaning, flushing, and hydrostatic testing log:

- a. Minimum flushing water velocity.
- b. Water treatment reports.
- c. Tracking checklist for managing and ensuring that all pipe sections have been cleaned, flushed, hydrostatically tested, and chemically treated.

1.7 CERTIFICATE OF READINESS DOCUMENTATION

Submit Certificate of Readiness documentation in accordance with Section TOTAL BUILDING COMMISSIONING for all equipment and systems including start-up reports; completed Pre-Functional Checklists; Testing, Adjusting, and Balancing (TAB) Report; HVAC Controls Start-Up Reports. Do not schedule Functional Performance Tests for the system until the Certificate

of Readiness for that system receives approval by the Contracting Officer. The Mechanical, Electrical, Controls, and TAB subcontractor representatives must sign and date the Certificate of Readiness.

PART 2 PRODUCTS

2.1 TEST EQUIPMENT

Provide all testing equipment required to perform testing for the systems to be commissioned, except for equipment specific to and used by TAB as required by Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC. Provide a sufficient quantity of two-way radios for each subcontractor. Submit list of Test Equipment and instrumentation to be used for testing including equipment/instrument identification number, equipment application or planned use, manufacturer, make, model, and serial number, and calibration history with certificates. Also list special equipment and proprietary tools specific to a piece of equipment required for testing.

2.1.1 Proprietary Equipment

Provide manufacturer's proprietary test equipment and software required by any equipment manufacturer for programming and/or start-up, whether specified or not. Provide manufacturer test equipment, demonstrate its use, and assist in the commissioning process as needed. Provide data logging equipment and software required to test equipment.

2.1.2 Calibration and Accuracy

Comply with equipment manufacturer's test equipment calibration procedures and intervals. Recalibrate test instruments immediately after instruments have been repaired resulting from being dropped or damaged. Affix calibration tags to test instruments. Furnish calibration records to Contracting Officer upon request.

Provide all testing equipment of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified. Unless otherwise noted, the following minimum requirements apply: Provide temperature sensors and digital thermometers with a certified calibration within the past year to an accuracy of 0.5 degrees F and a resolution of plus or minus 0.1 degrees F. Provide pressure sensors with an accuracy of plus or minus 2.0 percent of the value range being measured (not full range of meter) and calibrated within the last year.

PART 3 EXECUTION

3.1 MEETINGS

Attend all meetings in accordance with Section TOTAL BUILDING COMMISSIONING.

Provide timely updates on construction schedule changes so Commissioning Provider has scheduling information needed to execute commissioning process efficiently. Notify Contracting Officer of anticipated construction delays to commissioning activities not yet performed or not yet scheduled.

3.2 PREFUNCTIONAL CHECKS

Complete and sign Pre-Functional Checklists using the Commissioning

Provider's web-based commissioning software, or as specified by the commissioning plan. Provide manufacturer's installation manual for each type of unit. Perform all work in accordance with the manufacturer's published diagrams, recommendations, and equipment warranty requirements.

3.3 STARTUP AND INITIAL CHECKOUT

Document start-up and initial testing procedures including:

- a. Startup tests and factory testing reports.
- b. Manufacturer's representative start-up, operating, troubleshooting and maintenance procedures.
- d. Perform and clearly document system operational checks and quality control checks as they are completed, and providing a copy to the commissioning team.
- e. Correct deficiencies and sign the Certificate of Readiness for each system before functional performance testing

3.4 COMMISSIONING TESTING

Conduct Functional Performance Testing in accordance with Section TOTAL BUILDING COMMISSIONING and requirements in this section. Prior to Functional Performance Testing, complete all prerequisites in accordance with paragraph SEQUENCING AND SCHEDULING.

3.4.1 Preparation

Put equipment and systems into operation and continue operation during each working day of commissioning, as required. Verify temperature and pressure taps in accordance with Contract Documents. Provide a pressure/temperature plug at each water sensor which is an input point to control system.

Perform minor adjustments to equipment and systems during Functional Performance Tests as deemed necessary by the commissioning team. Where calibrated DDC sensors cannot be used to record test data, provide measuring instruments, logging devices, and data acquisition equipment to record data for the complete range of test data for the required test period.

3.4.2 Test Setup

Perform each test under conditions that simulate actual conditions as close as is practically possible. Provide all necessary materials and system modifications to produce the necessary flows, pressures, temperatures, and other conditions necessary to execute the test according to the specified conditions. At completion of the test, return the affected building equipment and systems to their pre-test condition.

3.4.3 Manufacturer's Representative

Provide a factory trained representative authorized by the equipment manufacturer to perform Functional Performance Testing for the following equipment:

Boilers

Packaged Direct-Expansion Refrigeration Equipment, including variable refrigerant flow (VRF) systems

Booster Pumps

Packaged Air Compressors

Water Quality and Chemical Treatment Systems

3.4.4 Sample Strategy

Perform Functional Performance Tests using the sample strategy described in Section TOTAL BUILDING COMMISSIONING. Prepare and complete a Functional Performance Test for each item of equipment or system to be tested. During testing, Government representatives may select the specific equipment or system to be tested for sample sizes less than 100 percent.

3.4.5 Simulating Conditions

Functional performance testing is conducted by simulating conditions at control devices to initiate a control system response. Before testing, calibrate all sensors, transducers and devices. Over-writing control input values through the control system is not acceptable unless approved by the Contracting Officer. Specific examples of simulating conditions are provided below. Do not simulate conditions when damage to the system or building may result.

- a. When varying static pressures inside ductwork cannot be simulated within the duct, and where a sensor signals the controls system to initiate sequences at various duct static pressures, it is acceptable to simulate the various pressures with a Pneumatic Squeeze-Bulb Type Signaling Device with gauge temporarily attached to the sensing tube leading to the transmitter. It is not acceptable to reset the various set-points, nor to simulate an electric analog signal (unless approved as noted above).
- b. Dirty filter pressure drops can be simulated by partially blocking filter face.
- c. Freeze-stat safeties can be simulated by packing portion of sensor with ice.
- d. High outside air temperatures can be simulated with a hair blower.
- e. Raising entering cooling coil temperatures by activating a heating/preheat coil can be used to simulate entering cooling coil conditions.
- f. Do not use signal generators to simulate sensor signals unless approved by the Contracting Officer, as noted above, for special cases.
- g. Control set points can be altered. For example, to see the air conditioning compressor lockout work at an outside air temperature below 55 degrees F, when the outside air temperature is above 55 degrees F, temporarily change the lockout set point to be 0 degrees F above the current outside air temperature. Caution: Set points are not to be raised or lowered to a point to cause damage to the

components, systems, or the building structure and/or contents.

- h. Test duct mounted smoke detectors in accordance with the manufacturer's recommendations. Perform the tests with air system at minimum airflow condition.
- i. Test current sensing relays used for fan and pump status signals to control system to indicate unit failure and run status by resetting the set point on the relay to simulate a lost belt or unit failure while the unit is running. Confirm that the failure alarm was generated and received at the control system. After the test is conducted, return the set point to its original set-point or a set-point as indicated by the Contracting Officer.

3.4.6 Duct Air Leakage Test (DALT) Report Review

All deficiencies must be resolved prior to DALT Report approval.

3.4.7 Testing, Adjusting, and Balancing (TAB) Report Verification

All deficiencies must be resolved prior to TAB Report approval.

3.4.8 HVAC Controls Test Procedures, Reports, and Trends Review

All deficiencies must be resolved prior to final acceptance.

3.5 RETESTING REQUIREMENTS

Abort tests if any deficiency prevents successful completion of the test or if any required commissioning team member is not present for the test. Re-test only after all deficiencies identified during the original tests have been corrected.

If sequence of operation in any of Functional Performance Tests fails, the Government's costs for witnessing further demonstration of that test procedure may be assigned to the Contractor as a deduct to their contracted price, including salary, travel costs, and per diem for Government commissioning team members. Correct deficiencies as identified by the commissioning team and retest the systems to be commissioned.

3.6 SYSTEM ACCEPTANCE

Systems may be partially accepted prior to seasonal testing if they comply with all construction contract and accepted design requirements that can be tested during initial Functional Performance Tests. All test procedures must be successful completed prior to full systems acceptance.

3.7 FULL-LOAD TESTS

Perform Initial Functional Performance Tests as soon as all contract work is completed, but prior to facility turnover. In addition to the Initial Functional Performance Tests, perform Functional Performance Tests of HVAC systems under full-load conditions. Develop and implement means of artificial loading to demonstrate the ability of the process cooling systems to handle peak process loads. Schedule Full-Load Functional Performance Tests in coordination with the Contracting Officer. Submit Full-Load Test Report within 14 days of test completion.

Execute full-load functional performance testing, witnessed by the

Contracting Officer. Correct deficiencies and make adjustments to O&M manuals and as-built drawings for applicable issues identified in any full load testing.

3.8 TRAINING

Coordinate, schedule, and document all required training. At a minimum, include the following items in the training report for commissioned systems:

- a. Complete commissioning documentation
- b. Complete O&M data
- c. Complete Training
- d. Purpose of equipment.
- e. Principle of how the equipment works.
- f. Important parts and assemblies.
- g. How the equipment achieves its purpose and necessary operating conditions.
- h. Most likely failure modes, causes and corrections.
- i. On site demonstration.
- j. Provide updates to O&M manuals based on field modifications.
- k. Provide training of the post-occupancy operations and maintenance staff.

-- End of Section --

SECTION 23 08 01.00 20

TESTING INDUSTRIAL VENTILATION SYSTEMS
04/06

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC. (AMCA)

AMCA 201 (2002; R 2011) Fans and Systems

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

ACGIH-2092S (2004) Industrial Ventilation: A Manual of Recommended Practice

1.2 DEFINITIONS

- a. Capture velocity: Air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture contaminated air at that point to cause it to flow into the hood.
- b. Capture zone: Controlled space around an industrial process that provides a safe and healthy workspace.
- c. Equilibrium performance point: The operating condition after sufficient start-up time that an air pollution control device reaches optimum efficiency. The manufacturer recommends the minimum start-up time for each device.
- d. Facility: A building or portion of a building in which contaminated air is controlled by the industrial ventilation system. This includes the shop space, equipment room, offices, restrooms and locker rooms affected by the industrial process.
- e. Full load condition: Condition in the facility where exhaust and replacement air systems operate simultaneously, as installed by the Contractor according to the design plans and specifications.
- f. Heating and cooling equipment: Equipment used to temper air in the facility. Equipment includes, but is not limited to: condensers, chillers, pumps, heat exchangers, heating and cooling coils, heat pumps, cooling towers, and duct heaters.
- g. Hood static pressure: Static pressure, in inches of water gage (wg), taken at 3 duct diameters from a flanged or plain hood or 1 duct diameter from a tapered hood.
- h. Manometer: An instrument for measuring pressure. Electronic or U-tube manometers with water or light oil are acceptable.

- i. Replacement air system: The mechanical system supplying air to a facility to replace exhausted air.
- j. Standard Temperature and Pressure: Air at standard conditions of 70 degrees Fahrenheit and 1 atmosphere.
- k. Static Pressure: The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches of wg.
- l. System Effect: The estimated loss in fan performance from non-uniform air flow at the fan's inlet or outlet.
- m. Test agency: A first tier subcontractor who is independent from the Contractor and the mechanical Sub-contractor except by the affiliation established by this contract.
- n. Transport velocity: Minimum air velocity, in feet per minute (fpm), required to prevent contaminants from settling, condensing, or pocketing in the ductwork.
- o. Velocity pressure: The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches of wg.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-06 Test Reports

- Preliminary review report; G
- Smoke tests report; G
- Fan operating points report; G
- Static pressure report; G
- Volume and velocity flow rates report; G
- Pitot traverse report; G

Submit 6 copies of an organized report bound in a durable, 3-ring water-resistant binder. The report shall contain a table of contents, an executive summary, an introduction, a results section and a discussion of the results. Include the reports specified in paragraphs entitled "Preliminary Review Report," "Smoke Test Reports," "Fan Operating Points Reports," "Static Pressure Report," "Volume and Velocity Flow Rates Report," and "Pitot Traverse Report" as appendices.

Submit field data and report forms in appendices separated by the fan system tested. Use the sample forms, "Replacement Air

System Test Data" and "Exhaust Air System Test Data," to summarize the tests for the appropriate fan. Forms other than those listed may be used; however, include all information required by these forms.

Document deficiencies and unmet design requirements identified during testing. Notify the Prime Contractor in writing, no later than 5 calendar days after encountering deficiency, describe the nature of the deficiency and a recommended course of action for resolution. Report daily temperature, humidity and barometric pressure readings. Note extreme weather and barometric pressure changes during the day.

SD-07 Certificates

Test agency Qualifications; G

Record of Document Submittal to Testing Agency; G

Work plan; G

List of test instruments; G

1.4 QUALITY ASSURANCE

1.4.1 Modification of References

Test the industrial ventilation system according to the referenced publications listed in paragraph entitled "References" and as modified by this section. Consider the advisory or recommended provisions, of the referred references, as mandatory.

1.4.2 Certification

1.4.2.1 Test Agency Qualifications

Submit, no later than 15 calendar days after contract award, information certifying that the test agency is not affiliated with any other company participating in work on this contract. The work of the test agency shall be limited to testing and making minor adjustments to the industrial ventilation system.

Use the sample form, "Test Agency Qualifications Sheet," to submit the following information:

- a. Verification of 5 years of experience as an agency in testing industrial ventilation systems or current member of either AABC or NEBB.
- b. References from five Contracting Officers of facilities with industrial ventilation systems that the agency has tested. A minimum of one facility shall have processes and contaminants similar to those generated by the facility in this project.
- c. Registration for Professional Engineer (PE) license or Certification for an Industrial Hygienist (CIH) or Test and Balance (TAB) Engineer for the lead test engineer. Submit PE license, CIH registration number, or TAB certification number. Include the discipline, date of issue, and expiration date. Engineers shall include the state of

issue.

- d. Confirmation of 5 years of industrial ventilation test experience for the lead test engineer. References from five Contracting Officers for facilities where the lead engineer has supervised industrial ventilation systems tests in the last 5 years.
- e. Verification of length of time lead engineer has been employed by a test and balance agency.

1.4.2.2 Record of Document Submittal to Testing Agency

Submit not later than 30 calendar days prior to the work plan submittal due date, a record of transmittal of the following documents to the approved independent testing agency. Information is required to develop a testing work plan and prepare for field testing.

- a. Copy of working as-built project drawings and specifications, including marked design changes. Changes current as of the date of transmission.
- b. Copies of all project submittals relating to the industrial ventilation system. Transmit copies of final record submittals including approval sheets.

1.4.2.3 Work Plan

Submit not later than 120 calendar days after contract award, but before start of work, steps to be taken by the lead engineer to accomplish the required testing. Submit the following:

- a. Memorandum of test procedure.
 - (1) Proposed dates for the preliminary review and test.
 - (2) Plan view showing proposed test locations (i.e. static pressure locations).
 - (3) Proposed pitot traverse reading locations.
- b. Test equipment to be used.
- c. Scaffolding and other Contractor's support equipment required to perform test.
- d. Factory representatives and other Contractor's support personnel who will be on site for testing.

1.4.2.4 List of Test Instruments

Submit a signed and dated list of test instruments, their application, manufacturer, model, serial number, range of operation, accuracy and date of calibration.

1.4.3 Test Requirements

The Contractor shall adjust and balance the industrial ventilation system according to Section 23 05 93 TESTING, ADJUSTING AND BALANCING FOR HVAC. An independent test agency shall test the industrial ventilation system

according to ACGIH-2092S and this section under full load conditions. For tempered supply air repeat the industrial ventilation systems test for the following conditions: plus or minus 20 percent minimum outdoor temperature design condition, .

1.4.4 Test Engineer

1.4.4.1 Field Work

The lead test engineer shall be present at the project site while testing is performed and shall be responsible for conducting, supervising, and managing of test work. Management includes health and safety of test agency employees.

1.4.4.2 Reporting Work

The lead test engineer shall prepare, sign, and date the test agenda, equipment list, and certified report.

1.4.5 Test Report

1.4.5.1 Preliminary Review Report

Submit a preliminary review report, see paragraph entitled "Preliminary Review" 15 calendar days prior to beginning the test.

1.4.5.2 Smoke Tests Report

Describe turbulent air flow and dead air spaces in and around the hood capture zone. Describe air flow exiting from the replacement air distribution device and the effect of room air currents on smoke capture. Report leaks in the ductwork, access door, and duct connectors to fan. Report smoke behavior as it exits from the exhaust stack and describe entrainment around the tested facility, nearby structures and any geographical features.

1.4.5.3 Fan Operating Points Report

Determine the difference between measured and design volume flow rate. Compare measured fan static pressure to manufacturer's performance data. Show the design and measured operating point for each fan on the corresponding fan curve. Report fans that cannot operate at speeds 25 percent faster than the measured speed while remaining within the boundaries of the fan curve and fan class. Identify fan motors that are operating at or near full load amperage.

1.4.5.4 Static Pressure Report

Include the following:

- a. Hood static pressures. Use tables to summarize test results by system.
- b. Fan static pressure, as defined by ACGIH-2092S, for replacement and exhaust air systems.
- c. Room static pressure, as compared to atmosphere , for each room in the facility.
- d. Static pressures that are inconsistent and the probable reason. For

example:

- (1) Inconsistent static pressure drop or increase in one or a series of hoods on the same branch;
- (2) Different static pressures for similar systems in the facility;
and
- (3) Decreasing static pressures as the hoods get closer to the exhaust fan inlet.

e. Differential pressure across air pollution control devices.

1.4.5.5 Volume and Velocity Flow Rates Report

Report volume flow rates and velocities in standard cubic feet per minute (cfm) and feet per minute (fpm), respectively, on the "Exhaust Air System Test Data" sample form or comparable form.

Convert measured volume flow rates to standard volume flow rates for locations with operating conditions other than standard temperature and pressure. The conversion may be ignored if the volume flow rate changes less than plus or minus one percent. Show both the actual and standard value for test points. Show a sample conversion equation.

Compare measured volume flow rates with the design value for each hood, the total exhaust air system, each replacement air distribution point and the total replacement air system. List the measured and design values in tabular form. Report the transport velocity for each branch submain and main duct in the exhaust air system.

Indicate if the test value is adequate or inadequate. Adequate hood volume flow rates and duct velocities are those with measured values within plus or minus 10 percent of design values. Adequate total system volume flow rates are those with measured values within plus or minus 10 percent of the design values.

1.4.5.6 Pitot Traverse Report

Use the "Pitot Traverse Data" sample form or comparable form to record pitot traverse readings. Submit the following data, as a minimum, for each test location:

- a. Velocity pressure and their corresponding velocities;
- b. Average velocity;
- c. Duct dimensions and area;
- d. Total measured volume flow rate; and
- e. Static pressure reading.

1.4.5.7 Deadline

Provide a simplified pass/fail report within 3 days after completion of testing. Provide a complete test report 15 days after completion of testing. The only exception is for the last seasonal work session which shall be completed by .

1.5 SAMPLE FORMS

1.5.1 Test Agency Qualification Sheet

TEST AGENCY QUALIFICATION SHEET	
DATE:	COMPLETED BY:
A. Agency Qualifications	
Agency Name:	
Address:	
Telephone Number:	
Years of experience testing industrial ventilation systems:	
Industrial facilities tested (5 required). Include the following:	
Facility Name, Address, Point of contact with telephone number;	
Dates of test;	
Type of operation tested;	
List of Contaminants;	
Number of fans;	
Type of exhaust hoods;	
Air cleaning devices; and	
Personnel performing the test.	
Attach letters of recommendation for tests performed at these facilities. Three facilities shall be of the type of operation to be tested.	
B. Lead Test Engineer Qualifications	

TEST AGENCY QUALIFICATION SHEET
Name:
Length of time lead engineer has worked with Agency:
Years of experience testing industrial ventilation systems:
Professional Engineering Information:
discipline:
license number:
issue date:
recertification date:
state of registration:
Industrial facilities tested (5 required). Include the following:
Facility Name, Address, Point of contact with telephone number;
Dates of Test;
Type of Operation;
List of Contaminants;
Number of Fans;
Type of Exhaust Hoods; and
Air Cleaning Devices.

1.5.2 Pitot Traverse Data - Rectangular Duct

PITOT TRAVERSE DATA - Rectangular Duct		
Test Date:		
Readings By:		Traverse By:
Static Pressure:		
Room:		Air Temperature:
Traverse Location:		Inside/Outside Duct Width:
Distance to Resistance Component:	Causing Component Distance:	Inside/Outside Duct Height:
		Inside Duct Area:
before:	before:	Required Velocity:
after:	after:	Required Actual Volume Flow Rate:
Velocity Pressure Reported as in.w.c. Units		

Pitot Traverse Matrix											
Velocity Pressure Readings (minimum center distance is 6 inches)											
<u>Point Position</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>Confirm</u>
A											
B											
C											
D											
E											
F											
G											
H											
I											
J											

Pitot Traverse Matrix											
Pressure Readings Converted to Velocity (FPM)											
Velocity Point Position	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	
A											
B											
C											
D											
E											
F											
G											
H											
I											
J											
Subtotal:											
Total Velocity/# Readings = Avg. Velocity x Duct Area = Actual Volume Flow Rate:											
$\frac{\text{FPM}}{\text{}} / \text{ } = \text{ } \text{ FPM} \times \text{ } \text{ SQ. FEET} = \text{ } \text{ ACFM}$											
* ACFM - actual cubic feet per minute											
REMARKS											

1.5.3 Pitot Traverse Data - Round Duct

PITOT TRAVERSE DATA - Round Duct		
Test Date:		
Readings By:		Traverse By:
Static Pressure:		
Room Number:		Air Temperature:
System/Unit:		Barometric Pressure:
Traverse Location:		Inside/Outside Duct DIA:
Distance to Resistance Component:	Causing Component Distance:	Inside Duct Area:
before:	before:	Required Velocity:
after:	after:	Required Actual Volume Flow Rate:
Velocity Pressure Reported as in.w.c. Units		

Pitot Traverse Matrix					
Duct Diameter	0-6 in.		6-48 in.		>48 in. or unstable velocity
Readings	12 (6/traverse)		20 (10/traverse)		40 (20/traverse)
TEST POINT	Velocity Pressure	Velocity	TEST POINT	Velocity Pressure	Velocity
1			21		
2			22		
2			22		
3			23		
4			24		
5			25		
6			26		
7			27		
8			28		
9			29		
10			30		

Pitot Traverse Matrix					
11			31		
12			32		
13			33		
14			34		
15			35		
16			36		
17			37		
18			38		
19			39		
20			40		
Confirm 1:			Confirm 1:		
Confirm 2:			Confirm 2:		
Velocity Sum:					
(Without Confirm Value)					
Velocity Sum/# Readings = Average Velocity x Duct Area = Actual Volume Flow					
Rate FPM / = FPM x SQ. Feet = ACFM					
REMARKS					

1.5.4 Exhaust Air System Test Data

EXHAUST AIR SYSTEM TEST DATA			
Test Dates:			
Readings By:			
Unit Number:		<u>Pressures (Pa)</u>	
Unit Location:		Fan Inlet Static:	
Make Model:		Fan Outlet Static:	
Model:		Fan Inlet Velocity:	
Serial Number:		Fan Static:	
		Fan Total:	
<u>Damper Positions</u>			
Hoods:		<u>Differential Pressure across air cleaning device</u>	
Submains:		Device	Delta P (Pa)
<u>Total Volume Test Location</u>			
Duct dia. before fan			
Duct dia. after fan			
		Fan Speed (RPM or RPS)	
		Motor Speed (RPM or RPS)	
<u>Resistance Causing Elements</u>			
<u>Type</u>	<u>Relationship to Fan</u>		<u>Pulley - Center to Center Distance</u>
	<u>before/after</u>	<u># Duct dia.</u>	
elbow			
damper			
expansion			Amperage - T1, T2, T3
contraction			Voltage - T1-2, T2-3, T3-1
plenum			

EXHAUST AIR SYSTEM TEST DATA			
			Temperature (W.B./D.B.)
			Outside Air
			Replacement Air
* RPM - revolutions per minute			W.B. - wet bulb
RPS - radians per second			D.B. - dry bulb

EXHAUST AIR SYSTEM TEST DATA			
Test Dates:			
Readings By:			
Unit Number:		<u>Pressures (inches of wg)</u>	
Unit Location:		Fan Inlet Static:	
Make Model:		Fan Outlet Static:	
Model:		Fan Inlet Velocity:	
Serial Number:		Fan Static:	
		Fan Total:	
<u>Damper Positions</u>			
Hoods:		<u>Differential Pressure across air cleaning device</u>	
Submains:		Device	Delta P (in. wg)
<u>Total Volume Test Location</u>			
Duct dia. before fan			
Duct dia. after fan			
		Fan Speed (RPM or RPS)	
		Motor Speed (RPM or RPS)	
<u>Resistance Causing Elements</u>			
<u>Type</u>	<u>Relationship to Fan</u>		<u>Pulley - Center to Center Distance</u>
	<u>before/after</u>	<u># Duct dia.</u>	

EXHAUST AIR SYSTEM TEST DATA			
elbow			
damper			
expansion			Amperage - T1, T2, T3
contraction			Voltage - T1-2, T2-3, T3-1
plenum			
			Temperature (W.B./D.B.)
			Outside Air
			Replacement Air
* RPM - revolutions per minute			W.B. - wet bulb
RPS - radians per second			D.B. - dry bulb

<u>VOLUME FLOW RATES (Standard Cubic Feet per Minute)</u>				
<u>SYSTEM</u>	<u>ACTUAL</u>	<u>DESIGN</u>	<u>ADEQUATE</u>	<u>INADEQUATE</u>
Total Volume				
<u>SUBMAIN</u>				
Submain name				
Submain name				
Submain name				
<u>HOODS</u>				
Hood name				
Hood name				
Hood name				
Hood name				
Hood name				
Hood name				
Hood name				
Hood name				
Hood name				
Hood name				

1.5.5 Replacement Air System Test Data

REPLACEMENT AIR SYSTEM TEST DATA			
Test Dates:			
Readings By:			
Unit Number:		<u>Pressures (inches of wg)</u>	
Unit Location:		Fan Inlet Static:	
Make Model:		Fan Outlet Static:	
Model:		Fan Inlet Velocity:	
Serial Number:		Fan Static:	
		Fan Total:	
<u>Damper Positions</u>			
		<u>Differential Pressure</u>	
Terminals:		across Filters	
Submains:		across Reheat Coil	
across Cooling Coil			
across Preheat Coil			
<u>Total Volume Test Location</u>			
<u>Total Volume Test Location</u>			
Duct dia. before fan		Fan Speed (RPM or RPS)	
Duct dia. after fan		Motor Speed (RPM or RPS)	
<u>Resistance Causing Elements</u>			
<u>Type</u>	<u>Relationship to Fan</u>		<u>Pulley - Center to Center Distance</u>
	<u>before/after</u>	<u># Duct dia.</u>	
elbow			
damper			
expansion			Amperage - T1, T2, T3

REPLACEMENT AIR SYSTEM TEST DATA			
contraction			Voltage - T1-2, T2-3,T3-1
plenum			
			Temperature (W.B./D.B.)
			Outside Air
			Replacement Air
			Mixed Air
* RPM - revolutions per minute			W.B. - wet bulb
RPS - radians per second			D.B. - dry bulb

<u>VOLUME FLOW RATES (Standard Cubic Feet per Minute)</u>				
<u>SYSTEM</u>	<u>ACTUAL</u>	<u>DESIGN</u>	<u>ADEQUATE</u>	<u>INADEQUATE</u>
Total Volume				
Outside Air Volume				
Return Air				
Ratio: Outside/Return				
<u>BRANCH</u>				
Branch name				
Branch name				
Branch name				
Branch name				
Branch name				
Branch name				
Branch name				

PART 2 PRODUCTS

Not used.

PART 3 EXECUTION

3.1 TEST PROCEDURE

Determine the static pressure of the work area relative to the outdoors and the following rooms: . Report the results.

3.1.1 Preliminary Review

Conduct a preliminary review of the facility 45 calendar days prior to beginning the test. Perform the following tasks and report the results of each task in the Preliminary Review Report.

- a. Locate industrial ventilation system components including hoods, hood transitions, ductwork, branch to main duct entries, elbows, expansions and contractions, fans, air pollution control devices, exhaust stacks, weather protection, replacement air plenums, and distribution devices. Show components on a single line drawing for each fan system.
- b. Review design drawings, specifications, and shop drawings to verify that testing can be performed on the system. Record, on the single line drawings, locations of planned pitot traverses of mains and branches and design velocities. Report potential test problems, such as inadequate space, to the Contracting Officer.
- c. Identify on the single line drawings the location of system fire protection components that may alter air flow, such as fire dampers.
- d. Identify on the single line drawings the location of emergency and spill sensors.
- e. Identify on the single line drawings the location of pressure differential sensors .
- f. Use AMCA 201 to identify system effects that occur at the inlet and outlet of each replacement and exhaust air fan.
- g. Verify that ductwork sizes, elbows and fittings, exhaust stacks and weather protection meet the design plans and specifications for both replacement and exhaust air systems.
- h. Verify that fans are rotating in the proper direction.
- i. Identify equipment such as fans, air pollution devices, heating coils, and controls, that do not meet the design plans and specifications.
- j. Obtain fan performance data.
- k. Verify that replacement air terminals including diffusers, louvers, and grilles are installed according to design plans and specifications.
- l. Obtain the differential pressure data and maximum operating pressures for air filtration devices including dirty and clean replacement air filters .

- m. Obtain the temperature and pressure control diagrams for the supply and exhaust industrial ventilation system.
- n. Record the nameplate data from each fan, motor, air cleaning device and .
- o. Record motor starter sizes and the type of thermal overload protection devices.
- p. Verify the following requirements unless otherwise specified in the individual section:
 - (1) Fan bearings have a minimum rated average life of 200,000 hours.
 - (2) Fan bases are level.
 - (3) Fan wheels are balanced and clear the housing.
 - (4) Fan shafts are of uniform diameter .
 - (5) Access to fan grease fittings and other routine maintenance equipment.
 - (6) Bearings are greased and the tube is full upon installation.
 - (7) Safety equipment, such as fan belt guards, are in place.

3.2 FIELD TESTS

3.2.1 Preliminary Procedures

Provide instruments and consumable equipment required to test the industrial ventilation system.

Before beginning the test:

- a. Close all windows and doors in the facility.
- b. Ensure that exhaust and replacement air ductwork and air intake sources are free from debris and dirt, through a visual inspection.
- c. Load the replacement air prefilters to the manufacturer's recommended maximum load condition.
- d. Run the exhaust air systems, containing air pollution control devices, for a sufficient time to obtain the manufacturer's recommended equilibrium performance point.
- e. Ensure that a duct leakage test is complete and accepted by the Contracting Officer.

3.2.2 Test Method

Test the ventilation under full load conditions according to ACGIH-2092S, Chapter 9 and this section. Record quantitative readings on sample forms, "Pitot Traverse Data, Round Duct," "Exhaust Air System Test Data," and "Replacement Air System Test Data."

The test engineer is authorized to readjust and rebalance the system if

minor adjustments will bring the system into compliance with the design. Minor adjustments include correcting fan rotation .

3.2.2.1 Air Quantity Readings

Use a pitot tube and manometer to measure the velocity pressures for the exhaust and replacement air systems. Determine the number and location of velocity pressure readings required for round and rectangular ducts according to ACGIH-2092S. Drill traverse access holes. Round ducts require two traverse access holes positioned 90 degrees apart.

Take pitot traverses away from air disturbing devices (i.e. elbows, branch entries, duct expansions, and hood transitions). Minimum distances are:

- a. Five (5) duct diameter of straight duct after the fan outlet; and
- b. Seven and one-half (7.5) duct diameters of straight duct after an air disturbing device.

When these distances of straight duct are not available, use a schematic drawing to note the disturbance producing device, and distance between the pitot traverse and the device.

Confirm one velocity pressure reading for each access hole after completing a traverse. Accept traverse data when the difference between the original and confirmation measurement is plus or minus 10 percent; otherwise repeat the traverse. Plug holes with cap plugs immediately after each traverse.

Convert velocity pressure readings to velocity before averaging the duct velocity. Calculate average velocity from velocity pressure readings and volume flow rates for the following locations:

- a. Replacement air fan outlet;
- b. Replacement air duct branch;
- c. Exhaust air duct branch, including hoods and submains;
- d. Exhaust fan inlet or outlet;
- f. Outside and return air ducts in recirculating replacement air system.

3.2.2.2 Air Velocity Meter Readings

A flow hood may be used for measuring office and restroom replacement air quantities. Do not substitute air velocity meter readings for manometer and pitot tube readings. Use air velocity meters to estimate the following:

- a. Velocity exiting from replacement air systems without ductwork;
- b. Crossdrafts in a room;
- c. Hood capture velocity;
- d. Duct velocities less than 600 fpm; and
- e. Slot velocities.

3.2.2.3 Static Pressure Readings

Take static pressure readings using a pitot tube and manometer. The following readings are required:

- a. Hood static pressure. Take readings at a distance of one duct diameter from tapered hoods, and 3 diameters from plain or flanged hoods;
- b. Replacement and exhaust fan inlet and outlet static pressure;
- c. Room static pressure as compared to outside the area controlled by industrial ventilation;
- e. Branch static pressure in the replacement and exhaust air system submain ductwork.

Verify test instrument readings correspond with attached static pressure gages

3.2.2.4 Control System Check-Out

Test warning system controls for the industrial ventilation system including the following:

- a. Above and below range alarms for room static pressure.
- b. Fan motor operating lights.
- c. Dampers operated by the control motor.

3.2.2.5 Other Readings

Take the following readings on each day testing is performed:

- a. Temperature readings after the system has stabilized and has been running for at least 4 hours:
 - (1) Wet bulb and dry bulb temperature of ancillary rooms, workspaces, replacement air, outside air, return air, .
 - (2) External temperature for fan and motor bearings on ventilation equipment.
- b. Record barometric pressure and altitude.

3.2.3 System Markings

Mark the settings and test ports to re-evaluate the industrial ventilation system during follow-up tests. Label test points before submitting the report. Use spray paint or another acceptable practice, i.e. permanent marker, to mark the airflow adjusting devices such as valves, splitters, dampers, and blast gates, so the devices can be returned to their original position if an unauthorized adjustment is made.

3.2.4 Test Verification

Notify Contracting Officer 30 calendar days prior to conducting the Test Verification. In the presence of the Contracting Officer, the test engineer shall repeat at least 10 percent of the test for each replacement and exhaust air system to verify the results. As a minimum, re-test the following readings:

- a. Total volume flow for each fan;
- b. Inlet and outlet static pressure for each fan;
- c. Volume flow and hood static pressure for the hood with the longest duct run from the exhaust fan; and
- d. Hood volume flow rates and total system volume flow rates which disagree with the design value;
- e. Differential pressure across each air pollution control device.

3.2.4.1 Test Result Disagreements

Static and velocity pressure test readings shall be within plus or minus 10 percent of the verification readings. When the difference between test and verification readings are greater than these acceptable values, the test engineer shall:

- a. Recalculate the test and verification results.
- b. Recalibrate test equipment.
- c. Retest the entire system.
- d. Verify the results.

3.2.5 Test Engineers Out-Brief

Provide a verbal summary for the Contracting Officer describing the condition of the industrial ventilation system. Report test data that does not meet the design criteria as defined in paragraph entitled "Field Test Reports."

-- End of Section --

SECTION 23 09 00

INSTRUMENTATION AND CONTROL FOR HVAC
02/19, CHG 3: 05/21

PART 1 GENERAL

1.1 SUMMARY

Provide a complete Direct Digital Control (DDC) system, except for the Front End which is specified in Section 25 10 10 UTILITY MONITORING AND CONTROL (UMCS) FRONT END AND INTEGRATION, suitable for the control of the heating, ventilating and air conditioning (HVAC) and other building-level systems as indicated and shown and in accordance with Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC, Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS for BACnet or Niagara BACnet systems, and other referenced Sections.

1.1.1 Proprietary Systems

1.1.1.1 Proprietary Systems Exempted From Open Protocol Requirements

The following systems are specifically exempted from the open protocol requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS:

- a. A simple split (DX) system consisting of a single indoor unit and a single outdoor unit from the same manufacturer.
- b. Systems in Table I (previously approved by the designer in accordance with UFC 3-410-02).

TABLE I: Systems Approved to Use Proprietary Communications		
System	Type (Multi-Split/VRF or Chiller/Boiler Plant)	Proprietary Multi-Split Engineering Tool Software Required (for Multi-Split/VRF only)

- c. A system (not already shown Table I) of multiple boilers or multiple chillers communicating with a proprietary network for which an approved request has been obtained and for which: all units are from the same manufacturer, they are all co-located in the same room, the network connecting them is fully contained in that room, and the units are operating using a common "plant" sequence of operation which stages the units in a manner that requires operational parameters be shared between them and which cannot be accomplished with a single lead-lag command from a third-party controller.

1.1.1.2 Implementation of Proprietary Systems

For proprietary systems exempted from open protocol requirements, a proprietary network and DDC hardware communicating via proprietary

protocol are permitted. For these systems a building control network meeting the requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS must also be provided, along with a gateway or interface to connect the proprietary system to the open building control network.

The proprietary system gateway or interface must provide the required functionality as shown on the points schedule. Scheduling, alarming, trending, overrides, network inputs, network outputs and other protocol related requirements must be met on the open protocol control system as specified in Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

1.1.1.3 Proprietary Multi-Split Engineering Tool Software

For each permitted proprietary systems in Table 1 shown as requiring Proprietary Multi-Split Engineering Tool Software, provide the software needed to replace a unit and configure the replacement. Submit hard copies of the software user manuals with the software submittal.

Submit Proprietary Multi-Split Engineering Tool Software on CD-ROM as a Technical Data Package. Submit 2 hard copies of the software user manual for each piece of software.

1.1.2 System Requirements

Provide systems meeting the requirements this Section and other Sections referenced by this Section, and which have the following characteristics:

- a. The system implements the control sequences of operation shown in the Contract Drawings using DDC hardware to control mechanical and electrical equipment
- b. The system meet the requirements of this specification as a stand-alone system and does not require connection to any other system.
- c. Control sequences reside in DDC hardware in the building. The building control network is not dependent upon connection to a Utility Monitoring and Control System (UMCS) Front End or to any other system for performance of control sequences. To the greatest extent practical, the hardware performs control sequences without reliance on the building network, unless otherwise pre-approved by the Contracting Officer.
- d. The hardware is installed such that individual control equipment can be replaced by similar control equipment from other equipment manufacturers with no loss of system functionality.
- e. All necessary documentation, configuration information, programming tools, programs, drivers, and other software are licensed to and otherwise remain with the Government such that the Government or their agents are able to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on the Contractor, Vendor or Manufacturer.
- f. Sufficient documentation and data, including rights to documentation and data, are provided such that the Government or their agents can execute work to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on the

Contractor, Vendor or Manufacturer.

- g. Hardware is installed and configured such that the Government or their agents are able to perform repair, replacement, and upgrades of individual hardware without further interaction with the Contractor, Vendor or Manufacturer.

1.1.3 End to End Accuracy

Select products, install and configure the system such that the maximum error of a measured value as read from the DDC Hardware over the network is less than the maximum allowable error specified for the sensor or instrumentation.

1.1.4 Verification of Dimensions

After becoming familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before performing any work.

1.1.5 Drawings

The Government will not indicate all offsets, fittings, and accessories that may be required on the drawings. Carefully investigate the mechanical, electrical, and finish conditions that could affect the work to be performed, arrange such work accordingly, and provide all work necessary to meet such conditions.

1.2 RELATED SECTIONS

Related work specified elsewhere:

- a. Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS for BACnet systems with or without Niagara Framework.
- b. Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC
- c. Section 23 09 93 SEQUENCES OF OPERATIONS FOR HVAC CONTROLS
- e. Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEMS (UMCS) FRONT END AND INTEGRATION
- g. Section 01 91 00.15 10 TOTAL BUILDING COMMISSIONING

1.3 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING
ENGINEERS (ASHRAE)

ASHRAE 135 (2020; Interpretation 1-8 2021; Errata 1-2
2021; Addenda CD 2021; Addenda BV-CE 2022;
Interpretation 9-12 2022; Interpretation
13-24 2023; Addenda BV-CF 2023; Errata 3
2023) BACnet-A Data Communication Protocol
for Building Automation and Control
Networks

ASHRAE FUN IP (2021) Fundamentals Handbook, I-P Edition

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C62.41 (1991; R 1995) Recommended Practice on
Surge Voltages in Low-Voltage AC Power
Circuits

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250 (2020) Enclosures for Electrical Equipment
(1000 Volts Maximum)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National
Electrical Code

NFPA 90A (2024) Standard for the Installation of
Air Conditioning and Ventilating Systems

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-410-02 (2018; with Change 2, 2021) Direct Digital
Control for HVAC and Other Building
Control Systems

UNDERWRITERS LABORATORIES (UL)

UL 5085-3 (2006; Reprint Jan 2022) UL Standard for
Safety Low Voltage Transformers - Part 3:
Class 2 and Class 3 Transformers

1.4 DEFINITIONS

The following list of definitions includes terms used in Sections referenced by this Section and are included here for completeness. The definitions contained in this Section may disagree with how terms are defined or used in other documents, including documents referenced by this Section. The definitions included here are the authoritative definitions for this Section and all Sections referenced by this Section.

After each term the protocol related to that term is included in parenthesis.

1.4.1 Alarm Generation (All protocols)

Alarm Generation is the monitoring of a value, comparison of the value to

alarm conditions and the creation of an alarm when the conditions set for the alarm are met. Note that this does NOT include delivery of the alarm to the final destination (such as a user interface) - see paragraph ALARM ROUTING in Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION.

1.4.2 Building Automation and Control Network (BACnet) (BACnet)

The term BACnet is used in two ways. First meaning the BACnet Protocol Standard - the communication requirements as defined by ASHRAE 135 including all annexes and addenda. The second to refer to the overall technology related to the ASHRAE 135 protocol.

1.4.3 BACnet Advanced Application Controller (B-AAC) (BACnet)

A hardware device BTL Listed as a B-AAC, which is required to support BACnet Interoperability Building Blocks (BIBBs) for scheduling and alarming, but is not required to support as many BIBBs as a B-BC.

1.4.4 BACnet Application Specific Controller (B-ASC) (BACnet)

A hardware device BTL Listed as a B-ASC, with fewer BIBB requirements than a B-AAC. It is intended for use in a specific application.

1.4.5 BACnet Building Controller (B-BC) (BACnet)

A hardware device BTL Listed as a B-BC. A general-purpose, field-programmable device capable of carrying out a variety of building automation and control tasks including control and monitoring via direct digital control (DDC) of specific systems and data storage for trend information, time schedules, and alarm data. Like the other BTL Listed controller types (B-AAC, B-ASC etc.) a B-BC device is required to support the server ("B") side of the ReadProperty and WriteProperty services, but unlike the other controller types it is also required to support the client ("A") side of these services. Communication between controllers requires that one of them support the client side and the other support the server side, so a B-BC is often used when communication between controllers is needed.

1.4.6 BACnet Broadcast Management Device (BBMD) (BACnet)

A communications device, typically combined with a BACnet router. A BBMD forwards BACnet broadcast messages to BACnet/IP devices and other BBMDs connected to the same BACnet/IP network. Each IP subnet that is part of a BACnet/IP network must have at least one BBMD. Note there are additional restrictions when multiple BBMDs share an IP subnet.

1.4.7 BACnet/IP (BACnet)

An extension of BACnet, Annex J, defines the use of a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP subnets that share the same BACnet network number. See also paragraph BACNET BROADCAST MANAGEMENT DEVICE.

1.4.8 BACnet Internetwork (BACnet)

Two or more BACnet networks, connected with BACnet routers. In a BACnet Internetwork, there exists only one message path between devices.

1.4.9 BACnet Interoperability Building Blocks (BIBBs) (BACnet)

A BIBB is a collection of one or more ASHRAE 135 Services intended to define a higher level of interoperability. BIBBs are combined to build the BACnet functional requirements for a device in a specification. Some BIBBs define additional requirements (beyond requiring support for specific services) in order to achieve a level of interoperability. For example, the BIBB DS-V-A (Data Sharing-View-A), which would typically be used by a front-end, not only requires the client to support the ReadProperty Service, but also provides a list of data types (Object / Properties) which the client must be able to interpret and display for the user.

In the BIBB shorthand notation, -A is the client side and -B is the server side.

The following is a list of some BIBBs used by this or referenced Sections:	
DS-COV-A	Data Sharing-Change of Value (A side)
DS-COV-B	Data Sharing-Change of Value (B side)
NM-RC-B	Network Management-Router Configuration (B side)
DS-RP-A	Data Sharing-Read Property (A side)
DS-RP-B	Data Sharing-Read Property (B side)
DS-RPM-A	Data Sharing-Read Property Multiple (A Side)
DS-RPM-B	Data Sharing-Read Property Multiple (B Side)
DS-WP-A	Data Sharing-Write Property (A Side)
DM-TS-B	Device Management-Time Synchronization (B Side)
DM-UTC-B	Device Management-UTC Time Synchronization (B Side)
DS-WP-B	Data Sharing-Write Property (B side)
SCHED-E-B	Scheduling-External (B side)
DM-OCD-B	Device Management-Object Creation and Deletion (B side)
AE-N-I-B	Alarm and Event-Notification Internal (B Side)
AE-N-E-B	Alarm and Event-Notification External (B Side)
T-VMT-I-B	Trending-Viewing and Modifying Trends Internal (B Side)
T-VMT-E-B	Trending-Viewing and Modifying Trends External (B Side)

1.4.10 BACnet Network (BACnet)

In BACnet, a portion of the control Internetwork consisting of one or more segments connected by repeaters. Networks are separated by routers.

1.4.11 BACnet Operator Display (B-OD) (BACnet)

A basic operator interface with limited capabilities relative to a B-OWS. It is not intended to perform direct digital control. A B-OD profile could be used for LCD devices, displays affixed to BACnet devices, handheld terminals or other very simple user interfaces.

1.4.12 BACnet Segment (BACnet)

One or more physical segments interconnected by repeaters (ASHRAE 135).

1.4.13 BACnet Smart Actuator (B-SA) (BACnet)

A simple actuator device with limited resources intended for specific applications.

1.4.14 BACnet Smart Sensor (B-SS) (BACnet)

A simple sensing device with limited resources.

1.4.15 BACnet Testing Laboratories (BTL) (BACnet)

Established by BACnet International to support compliance testing and interoperability testing activities and consists of BTL Manager and the BTL Working Group (BTL-WG). BTL also publishes Implementation Guidelines.

1.4.16 BACnet Testing Laboratories (BTL) Listed (BACnet)

A device that has been listed by BACnet Testing Laboratory. Devices may be certified to a specific device profile, in which case the listing indicates that the device supports the required capabilities for that profile, or may be listed as "other".

1.4.17 Binary (All protocols)

A two-state system where an "ON" condition is represented by a high signal level and an "OFF" condition is represented by a low signal level. 'Digital' is sometimes used interchangeably with 'binary'.

1.4.18 Broadcast (BACnet)

Unlike most messages, which are intended for a specific recipient device, a broadcast message is intended for all devices on the network.

1.4.19 Building Control Network (BCN) (All protocols)

The network connecting all DDC Hardware within a building (or specific group of buildings).

1.4.20 Building Point of Connection (BPOC) (All protocols)

A FPOC for a Building Control System. (This term is being phased out of use in preference for FPOC but is still used in some specifications and criteria. When it was used, it typically referred to a piece of control hardware. The current FPOC definition typically refers instead to IT hardware.)

1.4.21 Commandable (All protocols)

See Overridable.

1.4.22 Commandable Objects (BACnet)

Commandable Objects have a Commandable Property, Priority_Array, and Relinquish_Default Property as defined in ASHRAE 135, Clause 19.2, Command Prioritization.

1.4.23 Configurable (All protocols)

A property, setting, or value is configurable if it can be changed via hardware settings on the device, via the use of engineering software or over the control network from the front end, and is retained through (after) loss of power.

In a BACnet system, a property, setting, or value is configurable if it can be changed via one or more of:

- 1) via BACnet services (including proprietary BACnet services)
- 2) via hardware settings on the device

Note this is more stringent than the ASHRAE 135 definition.

1.4.24 Control Logic Diagram (All protocols)

A graphical representation of control logic for multiple processes that make up a system.

1.4.25 Device (BACnet)

A Digital Controller that contains a BACnet Device Object and uses BACnet to communicate with other devices.

1.4.26 Device Object (BACnet)

Every BACnet device requires one Device Object, whose properties represent the network visible properties of that device. Every Device Object requires a unique Object Identifier number on the BACnet Internetwork. This number is often referred to as the device instance or device ID.

1.4.27 Device Profile (BACnet)

A collection of BIBBs determining minimum BACnet capabilities of a device, defined in ASHRAE 135. Standard device profiles include BACnet Advanced Workstations (B-AWS), BACnet Building Controllers (B-BC), BACnet Advanced Application Controllers (B-AAC), BACnet Application Specific Controllers (B-ASC), BACnet Smart Actuator (B-SA), and BACnet Smart Sensor (B-SS).

1.4.28 Digital Controller (All protocols)

An electronic controller, usually with internal programming logic and digital and analog input/output capability, which performs control functions.

1.4.29 Direct Digital Control (DDC) (All protocols)

Digital controllers performing control logic. Usually the controller directly senses physical values, makes control decisions with internal

programs, and outputs control signals to directly operate switches, valves, dampers, and motor controllers.

1.4.30 Field Point of Connection (FPOC) (All protocols)

The FPOC is the point of connection between the UMCS IP Network and the field control network (either an IP network, a non-IP network, or a combination of both). The hardware at this location which provides the connection is generally an IT device such as a switch, IP router, or firewall.

In general, the term "FPOC Location" means the place where this connection occurs, and "FPOC Hardware" means the device that provides the connection. Sometimes the term "FPOC" is used to mean either and its actual meaning (i.e. location or hardware) is determined by the context in which it is used.

1.4.31 Gateway (All protocols)

A device that translates from one protocol application data format to another. Devices that change only the transport mechanism of the protocol - "translating" from TP/FT-10 to Ethernet/IP or from BACnet MS/TP to BACnet over IP for example - are not gateways as the underlying data format does not change. Gateways are also called Communications Bridges or Protocol Translators.

1.4.32 IEEE 802.3 Ethernet (All protocols)

A family of local-area-network technologies providing high-speed networking features over various media, typically Cat 5, 5e or Cat 6 twisted pair copper or fiber optic cable.

1.4.33 Internet Protocol (IP, TCP/IP, UDP/IP) (All protocols)

A communication method, the most common use is the World Wide Web. At the lowest level, it is based on Internet Protocol (IP), a method for conveying and routing packets of information over various LAN media. Two common protocols using IP are User Datagram Protocol (UDP) and Transmission Control Protocol (TCP). UDP conveys information to well-known "sockets" without confirmation of receipt. TCP establishes connections, also known as "sessions", which have end-to-end confirmation and guaranteed sequence of delivery.

1.4.34 Input/Output (I/O) (All protocols)

Physical inputs and outputs to and from a device, although the term sometimes describes network or "virtual" inputs or outputs. See also "Points".

1.4.35 I/O Expansion Unit (All protocols)

An I/O expansion unit provides additional point capacity to a digital controller

1.4.36 IP subnet (All protocols)

A group of devices which share a defined range IP addresses. Devices on a

common IP subnet can share data (including broadcasts) directly without the need for the traffic to traverse an IP router.

1.4.37 Local-Area Network (LAN) (All protocols)

A communication network that spans a limited geographic area and uses the same basic communication technology throughout.

1.4.38 Local Display Panels (LDPs) (All protocols)

A DDC Hardware with a display and navigation buttons, and must provide display and adjustment of points as shown on the Points Schedule and as indicated.

1.4.39 MAC Address (All protocols)

Media Access Control address. The physical device address that identifies a device on a Local Area Network.

1.4.40 Master-Slave/Token-Passing (MS/TP) (BACnet)

Data link protocol as defined by the BACnet standard. Multiple speeds (data rates) are permitted by the BACnet MS/TP standard.

1.4.41 Monitoring and Control (M&C) Software (All protocols)

The UMCS 'front end' software which performs supervisory functions such as alarm handling, scheduling and data logging and provides a user interface for monitoring the system and configuring these functions.

1.4.42 Network Number (BACnet)

A site-specific number assigned to each network. This network number must be unique throughout the BACnet Internetwork.

1.4.43 Object (BACnet)

An ASHRAE 135 Object. The concept of organizing BACnet information into standard components with various associated Properties. Examples include Analog Input objects and Binary Output objects.

1.4.44 Object Identifier (BACnet)

A grouping of two Object properties: Object Type (e.g. Analog Value, Schedule, etc.) and Object Instance (in this case, a number). Object Identifiers must be unique within a device.

1.4.45 Object Instance (BACnet)

See paragraph OBJECT IDENTIFIER

1.4.46 Object Properties (BACnet)

Attributes of an object. Examples include present value and high limit properties of an analog input object. Properties are defined in ASHRAE 135; some are optional and some are required. Objects are controlled by reading from and writing to object properties.

1.4.47 Operator Configurable (All protocols)

Operator configurable values are values that can be changed from a single common front end user interface across multiple vendor systems.

For non Niagara-based BACnet systems, a property, setting, or value in a device is Operator Configurable when it is Configurable and is either:

- a. a Writable Property of a Standard BACnet Object; or
- b. a Property of a Standard BACnet Object that is Writable when Out_Of_Service is TRUE and Out_Of_Service is Writable.

1.4.48 Override (All protocols)

Changing the value of a point outside of the normal sequence of operation where the change has priority over the sequence and where there is a mechanism for releasing the change such that the point returns to the normal value. Overrides persist until released or overridden at the same or higher priority but are not required to persist through a loss of power. Overrides are often used by operators to change values, and generally originate at a user interface (workstation or local display panel).

1.4.49 Packaged Equipment (All protocols)

Packaged equipment is a single piece of equipment provided by a manufacturer in a substantially complete and operable condition, where the controls (DDC Hardware) are factory installed, and the equipment is sold and shipped from the manufacturer as a single entity. Disassembly and reassembly of a large piece of equipment for shipping does not prevent it from being packaged equipment. Package units may require field installation of remote sensors. Packaged equipment is also called a "packaged unit".

Note industry may use the term "Packaged System" to mean a collection of equipment that is designed to work together where each piece of equipment is packaged equipment and there is a network that connects the equipment together. A "packaged system" of this type is NOT packaged equipment; it is a collection of packaged equipment, and each piece of equipment must individually meet specification requirements.

1.4.50 Packaged Unit (All protocols)

See packaged equipment.

1.4.51 Performance Verification Test (PVT) (All protocols)

The procedure for determining if the installed BAS meets design criteria prior to final acceptance. The PVT is performed after installation, testing, and balancing of mechanical systems. Typically the PVT is performed by the Contractor in the presence of the Government.

1.4.52 Physical Segment (BACnet)

A single contiguous medium to which BACnet devices are attached (ASHRAE 135).

1.4.53 Polling (All protocols)

A device periodically requesting data from another device.

1.4.54 Points (All protocols)

Physical and virtual inputs and outputs. See also paragraph INPUT/OUTPUT (I/O).

1.4.55 Proportional, Integral, and Derivative (PID) Control Loop (All protocols)

Three parameters used to control modulating equipment to maintain a setpoint. Derivative control is often not required for HVAC systems (leaving "PI" control).

1.4.56 Proprietary (BACnet)

Within the context of BACnet, any extension of or addition to object types, properties, PrivateTransfer services, or enumerations specified in ASHRAE 135. Objects with Object_Type values of 128 and above are Proprietary Objects. Properties with Property_Identifier of 512 and above are proprietary Properties.

1.4.57 Protocol Implementation Conformance Statement (PICS) (BACnet)

A document, created by the manufacturer of a device, which describes which portions of the BACnet standard may be implemented by a given device. ASHRAE 135 requires that all ASHRAE 135 devices have a PICS, and also defines a minimum set of information that must be in it. A device as installed for a specific project may not implement everything in its PICS.

1.4.58 Repeater (All protocols)

A device that connects two control network segments and retransmits all information received on one side onto the other.

1.4.59 Router (All protocols)

A device that connects two ASHRAE 135 networks and controls traffic between the two by retransmitting signals received from one side onto the other based on the signal destination. Routers are used to subdivide a BACnet internetwork and to limit network traffic.

1.4.60 Segment (All protocols)

A 'single' section of a control network that contains no repeaters or routers. There is generally a limit on the number of devices on a segment, and this limit is dependent on the topology/media and device type.

1.4.61 Standard BACnet Objects (BACnet)

Objects with Object_Type values below 128 and specifically enumerated in Clause 21 of ASHRAE 135. Objects which are not proprietary. See paragraph PROPRIETARY.

1.4.62 Standard BACnet Properties (BACnet)

Properties with Property_Identifier values below 512 and specifically enumerated in Clause 21 of ASHRAE 135. Properties which are not proprietary. See Proprietary.

1.4.63 Standard BACnet Services (BACnet)

ASHRAE 135 services other than ConfirmedPrivateTransfer or UnconfirmedPrivateTransfer. See paragraph PROPRIETARY.

1.4.64 UMCS (All protocols)

UMCS stands for Utility Monitoring and Control System. The term refers to all components by which a project site monitors, manages, and controls real-time operation of HVAC and other building systems. These components include the UMCS "front-end" and all field building control systems connected to the front-end. The front-end consists of Monitoring and Control Software (user interface software), browser-based user interfaces and network infrastructure.

The network infrastructure (the "UMCS Network"), is an IP network connecting multiple building or facility control networks to the Monitoring and Control Software.

1.4.65 UMCS Network (All protocols)

The UMCS Network connects multiple building or facility control networks to the Monitoring and Control Software.

1.4.66 Writable Property (BACnet)

A Property is Writable when it can be changed through the use of one or more of the WriteProperty services defined in ASHRAE 135, Clause 15 regardless of the value of any other Property. Note that in the ASHRAE 135 standard, some Properties may be writable when the Out of Service Property is TRUE; for purposes of this Section, Properties that are only writable when the Out of Service Property is TRUE are not considered to be Writable.

1.5 PROJECT SEQUENCING

TABLE II: PROJECT SEQUENCING lists the sequencing of submittals as specified in paragraph SUBMITTALS (denoted by an 'S' in the 'TYPE' column) and activities as specified in PART 3 EXECUTION (denoted by an 'E' in the 'TYPE' column). TABLE II does not specify overall project milestone and completion dates.

- a. Sequencing for Submittals: The sequencing specified for submittals is the deadline by which the submittal must be initially submitted to the Government. Following submission there will be a Government review period as specified in Section 01 33 00 SUBMITTAL PROCEDURES. If the submittal is not accepted by the Government, revise the submittal and resubmit it to the Government within 14 days of notification that the submittal has been rejected. Upon resubmittal there will be an additional Government review period. If the submittal is not accepted the process repeats until the submittal is accepted by the Government.
- b. Sequencing for Activities: The sequencing specified for activities

indicates the earliest the activity may begin.

- c. Abbreviations: In TABLE II the abbreviation AAO is used for 'after approval of' and 'ACO' is used for 'after completion of'.

TABLE II. PROJECT SEQUENCING			
ITEM #	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY OR DEADLINE FOR SUBMITTAL)
1	S	Existing Conditions Report	
2	S	DDC Contractor Design Drawings	
3	S	Manufacturer's Product Data	
4	S	Pre-construction QC Checklist	
5	E	Install Building Control System	AAO #1 thru #4
6	E	Start-Up and Start-Up Testing	ACO #5
7	S	Post-Construction QC Checklist	ACO #6
8	S	Programming Software Configuration Software	ACO #6
9	S	Draft As-Built Drawings	ACO #6
10	S	Start-Up Testing Report	ACO #6
11	S	PVT Procedures	before schedule start of #12 and AAO #10
12	E	Execute PVT	AAO #9 and #11

TABLE II. PROJECT SEQUENCING			
ITEM #	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY OR DEADLINE FOR SUBMITTALS)
13	S	PVT Report	ACO #12
14	S	Controller Application Programs Controller Configuration Settings	AAO #13
15	S	Final As-Built Drawings	AAO #13
16	S	O&M Instructions	AAO #15
17	S	Training Documentation	AAO #10 and before scheduled start of #18
18	E	Training	AAO #16 and #17
19	S	Closeout QC Checklist	ACO #18

1.6 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

DDC Contractor Design Drawings; G

Draft As-Built Drawings; G

Final As-Built Drawings; G

SD-03 Product Data

Programming Software; G

Controller Application Programs; G

Configuration Software; G

Controller Configuration Settings; G

Proprietary Multi-Split Engineering Tool Software; G

Manufacturer's Product Data; G

SD-05 Design Data

Boiler Or Chiller Plant Gateway Request

SD-06 Test Reports

Pre-Construction Quality Control (QC) Checklist; G

Post-Construction Quality Control (QC) Checklist; G

Start-Up Testing Report; G

PVT Procedures; G

PVT Report; G

SD-10 Operation and Maintenance Data

Operation and Maintenance (O&M) Instructions; G

Training Documentation; G

SD-11 Closeout Submittals

Enclosure Keys; G

Password Summary Report; G

Closeout Quality Control (QC) Checklist; G

1.7 DATA PACKAGE AND SUBMITTAL REQUIREMENTS

Technical data packages consisting of technical data and computer software (meaning technical data which relates to computer software) which are specifically identified in this project and which may be defined/required in other specifications must be delivered strictly in accordance with the CONTRACT CLAUSES and in accordance with the Contract Data Requirements List, DD Form 1423. Data delivered must be identified by reference to the particular specification paragraph against which it is furnished. All submittals not specified as technical data packages are considered 'shop

drawings' under the Federal Acquisition Regulation Supplement (FARS) and must contain no proprietary information and be delivered with unrestricted rights.

1.8 SOFTWARE FOR DDC HARDWARE AND GATEWAYS

Provide all software related to the programming and configuration of DDC Hardware and Gateways as indicated. License all Software to the project site. The term "controller" as used in these requirements means both DDC Hardware and Gateways.

1.8.1 Configuration Software

For each type of controller, provide the configuration tool software in accordance with Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS. Submit hard copies of the software user manuals for each software with the software submittal.

Submit Configuration Software on CD-ROM as a Technical Data Package. Submit hard copies of the software user manual for each piece of software.

1.8.2 Controller Configuration Settings

For each controller, provide copies of the installed configuration settings as source code compatible with the configuration tool software for that controller in accordance with Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

Submit Controller Configuration Settings on CD-ROM as a Technical Data Package. Include on the CD-ROM a list or table of contents clearly indicating which files are associated with each device. Submit 2 copies of the Controller Configuration Settings CD-ROM.

1.8.3 Programming Software

For each type of programmable controller, provide the programming software in accordance with Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS. Submit hard copies of software user manuals for each software with the software submittal.

Submit Programming Software on CD-ROM as a Technical Data Package. Submit hard copies of the software user manual for each piece of software.

1.8.4 Controller Application Programs

For each programmable controller, provide copies of the application program as source code compatible with the programming software for that controller in accordance with Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

Submit Controller Application Programs on CD-ROM as a Technical Data Package. Include on the CD-ROM a list or table of contents clearly indicating which application program is associated with each device. Submit 2 copies of the Controller Application Programs CD-ROM.

1.9 BOILER OR CHILLER PLANT GATEWAY REQUEST

If requesting the use of a gateway to a boiler or chiller plant as indicated in paragraph Proprietary Systems Exempted From Open Protocol Requirements, submit a Boiler or Chiller Plant Gateway Request describing the configuration of the boilers or chillers including model numbers for equipment and controllers, the sequence of operation for the units, and a justification for the need to operate the units on a shared non-BACnet network.

1.10 QUALITY CONTROL CHECKLISTS

The QC Checklist for BACnet Systems in APPENDIX A of this Section must be completed by the Contractor's Chief Quality Control (QC) Representative and submitted as indicated.

The QC Representative must verify each item indicated and initial in the space provided to indicate that the requirement has been met. The QC Representative must sign and date the Checklist prior to submission to the Government.

1.10.1 Pre-Construction Quality Control (QC) Checklist

Complete items indicated as Pre-Construction QC Checklist items in the QC Checklist. Submit four copies of the Pre-Construction QC Checklist.

1.10.2 Post-Construction Quality Control (QC) Checklist

Complete items indicated as Post-Construction QC Checklist items in the QC Checklist. Submit four copies of the Post-Construction QC Checklist.

1.10.3 Closeout Quality Control (QC) Checklist

Complete items indicated as Closeout QC Checklist items in the QC Checklist. Submit four copies of the Closeout QC Checklist.

PART 2 PRODUCTS

Provide products meeting the requirements of Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC, Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS for BACnet or Niagara BACnet systems, other referenced Sections, and this Section.

2.1 GENERAL PRODUCT REQUIREMENTS

Units of the same type of equipment must be products of a single manufacturer. Each major component of equipment must have the manufacturer's name and address, and the model and serial number in a conspicuous place. Materials and equipment must be standard products of a manufacturer regularly engaged in the manufacturing of these and similar products. The standard products must have been in a satisfactory commercial or industrial use for two years prior to use on this project. The two year use must include applications of equipment and materials under similar circumstances and of similar size. DDC Hardware not meeting the two-year field service requirement is acceptable provided it has been successfully used by the Contractor in a minimum of two previous

projects. The equipment items must be supported by a service organization. Items of the same type and purpose must be identical, including equipment, assemblies, parts and components.

2.2 PRODUCT DATA

Provide manufacturer's product data sheets documenting compliance with product specifications for each product provided under Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC, Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS, or this Section. Provide product data for all products in a single indexed compendium, organized by product type.

For all BACnet hardware: for each manufacturer, model and version (revision) of DDC Hardware provide the Protocol Implementation Conformance Statement (PICS) in accordance with Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

Submit Manufacturer's Product Data on CD-ROM.

2.3 OPERATION ENVIRONMENT

Unless otherwise specified, provide products rated for continuous operation under the following conditions:

- a. Pressure: Pressure conditions normally encountered in the installed location.
- b. Vibration: Vibration conditions normally encountered in the installed location.
- c. Temperature:
 - (1) Products installed indoors: Ambient temperatures in the range of 32 to 112 degrees F and temperature conditions outside this range normally encountered at the installed location.
 - (2) Products installed outdoors or in unconditioned indoor spaces: Ambient temperatures in the range of -35 to +151 degrees F and temperature conditions outside this range normally encountered at the installed location.
- d. Humidity: 10 to 95 percent relative humidity, noncondensing and humidity conditions outside this range normally encountered at the installed location.

2.4 WIRELESS CAPABILITY

For products incorporating any wireless capability (including but not limited to radio frequency (RF), infrared and optical), provide products for which wireless capability can be permanently disabled at the device. Optical and infrared capabilities may be disabled via a permanently affixed opaque cover plate.

2.5 ENCLOSURES

Enclosures supplied as an integral (pre-packaged) part of another product are acceptable. Provide two Enclosure Keys for each lockable enclosure on a single ring per enclosure with a tag identifying the enclosure the keys

operate. Provide enclosures meeting the following minimum requirements:

2.5.1 Outdoors

For enclosures located outdoors, provide enclosures meeting NEMA 250 Type 3 requirements.

2.5.2 Mechanical and Electrical Rooms

For enclosures located in mechanical or electrical rooms, provide enclosures meeting NEMA 250 Type 2 requirements.

2.5.3 Other Locations

For enclosures in other locations including but not limited to occupied spaces, above ceilings, and in plenum returns, provide enclosures meeting NEMA 250 Type 1 requirements.

2.6 WIRE AND CABLE

Provide wire and cable meeting the requirements of NFPA 70 and NFPA 90A in addition to the requirements of this specification and referenced specifications.

2.6.1 Terminal Blocks

For terminal blocks which are not integral to other equipment, provide terminal blocks which are insulated, modular, feed-through, clamp style with recessed captive screw-type clamping mechanism, suitable for DIN rail mounting, and which have enclosed sides or end plates and partition plates for separation.

2.6.2 Control Wiring for Binary Signals

For Control Wiring for Binary Signals, provide 18 AWG copper or thicker wire rated for 300-volt service.

2.6.3 Control Wiring for Analog Signals

For Control Wiring for Analog Signals, provide 18 AWG or thicker, copper, single- or multiple-twisted wire meeting the following requirements:

- a. minimum 2 inch lay of twist
- b. 100 percent shielded pairs
- c. at least 300-volt insulation
- d. each pair has a 20 AWG tinned-copper drain wire and individual overall pair insulation
- e. cables have an overall aluminum-polyester or tinned-copper cable-shield tape, overall 20 AWG tinned-copper cable drain wire, and overall cable insulation.

2.6.4 Power Wiring for Control Devices

For 24-volt circuits, provide insulated copper 18 AWG or thicker wire rated for 300 VAC service. For 120-volt circuits, provide 14 AWG or

thicker stranded copper wire rated for 600-volt service.

2.6.5 Transformers

Provide UL 5085-3 approved transformers. Select transformers sized so that the connected load is no greater than 80 percent of the transformer rated capacity.

PART 3 EXECUTION

3.1 INSTALLATION

Fully install and test the control system in accordance Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC, Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS for BACnet or Niagara BACnet systems, and this Section.

3.1.1 Dielectric Isolation

Provide dielectric isolation where dissimilar metals are used for connection and support. Install control system in a manner that provides clearance for control system maintenance by maintaining access space required to calibrate, remove, repair, or replace control system devices. Install control system such that it does not interfere with the clearance requirements for mechanical and electrical system maintenance.

3.1.2 Penetrations in Building Exterior

Make all penetrations through and mounting holes in the building exterior watertight.

3.1.3 Device Mounting Criteria

Install devices in accordance with the manufacturer's recommendations and as indicated and shown. Provide a weathershield for all devices installed outdoors. Provide clearance for control system maintenance by maintaining access space required to calibrate, remove, repair, or replace control system devices. Provide clearance for mechanical and electrical system maintenance; do not not interfere with the clearance requirements for mechanical and electrical system maintenance.

3.1.4 Labels and Tags

Key all labels and tags to the unique identifiers shown on the As-Built drawings. For labels exterior to protective enclosures provide engraved plastic labels mechanically attached to the enclosure or DDC Hardware. Labels inside protective enclosures may be attached using adhesive, but must not be hand written. For tags, provide plastic or metal tags mechanically attached directly to each device or attached by a metal chain or wire.

- a. Label all Enclosures and DDC Hardware.
- b. Tag Airflow measurement arrays (AFMA) with flow rate range for signal output range, duct size, and pitot tube AFMA flow coefficient.
- c. Tag duct static pressure taps at the location of the pressure tap

3.1.5 Surge Protection

3.1.5.1 Power-Line Surge Protection

Protect equipment connected to AC circuits to withstand power-line surges in accordance with IEEE C62.41. Do not use fuses for surge protection.

3.1.5.2 Surge Protection for Transmitter and Control Wiring

Protect DDC hardware against or provided DDC hardware capable of withstanding surges induced on control and transmitter wiring installed outdoors and as shown. Protect equipment against the following two waveforms:

- a. A waveform with a 10-microsecond rise time, a 1000-microsecond decay time and a peak current of 60 amps.
- b. A waveform with an 8-microsecond rise time, a 20-microsecond decay time and a peak current of 500 amperes.

3.1.6 Basic Cybersecurity Requirements

3.1.6.1 Passwords

For all devices with a password, change the password from the default password. Do not use the same password for more than one device. Coordinate selection of passwords with . Provide a Password Summary Report documenting the password for each device and describing the procedure to change the password for each device.

Provide two hardcopies of the Password Summary Report, each copy in its own sealed envelope.

3.1.6.2 Wireless Capability

Unless otherwise indicated, disable wireless capability (including but not limited to radio frequency (RF), infrared and optical) for all devices with wireless capability. Optical and infrared capabilities may be disabled via a permanently affixed opaque cover plate. Password protecting a wireless connections does not meet this requirement; the wireless capability must be disabled.

3.1.6.3 IP Network Physical Security

Install all IP Network media in conduit. Install all IP devices including but not limited to IP-enabled DDC hardware and IP Network Hardware in lockable enclosures.

3.2 DRAWINGS AND CALCULATIONS

Provide drawings in the form and arrangement indicated and shown. Use the same abbreviations, symbols, nomenclature and identifiers shown. Assign a unique identifier as shown to each control system element on a drawing. When packaging drawings, group schedules by system. When space allows, it is permissible to include multiple schedules for the same system on a single sheet. Except for drawings covering all systems, do not put information for different systems on the same sheet.

Submit hardcopy drawings on ISO A1 34 by 22 inches sheets, and electronic

drawings in PDF and in Autodesk Revit 2023 format. In addition, submit electronic drawings in editable Excel format for all drawings that are tabular, including but not limited to the Point Schedule and Equipment Schedule.

- a. Submit DDC Contractor Design Drawings consisting of each drawing indicated with pre-construction information depicting the intended control system design and plans. Submit DDC Contractor Design Drawings as a single complete package: hard copies and copies on CD-ROM.
- b. Submit Draft As-Built Drawings consisting of each drawing indicated updated with as-built data for the system prior to PVT. Submit Draft As-Built Drawings as a single complete package: hard copies and copies on CD-ROM.
- c. Submit Final As-Built Drawings consisting of each drawing indicated updated with all final as-built data. Final As-Built Drawings as a single complete package: hard copies and copies on CD-ROM.

3.2.1 Sample Drawings

Sample drawings in electronic format are available at the Whole Building Design Guide page for this section:

<http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-23-09-00>

These drawings may prove useful in demonstrating expected drawing formatting and example content and are provided for illustrative purposes only. Note that these drawings do not meet the content requirements of this Section and must be completed to meet project requirements.

3.2.2 Drawing Index and Legend

Provide an HVAC Control System Drawing Index showing the name and number of the building, military site, State or other similar designation, and Country. In the Drawing Index, list all Contractor Design Drawings, including the drawing number, sheet number, drawing title, and computer filename when used. In the Design Drawing Legend, show and describe all symbols, abbreviations and acronyms used on the Design Drawings. Provide a single Index and Legend for the entire drawing package.

3.2.3 Thermostat and Occupancy Sensor Schedule

Provide a thermostat and occupancy sensor schedule containing each thermostat's unique identifier, room identifier and control features and functions as shown. Provide a single thermostat and occupancy sensor schedule for the entire project.

3.2.4 Valve Schedule

Provide a valve schedule containing each valve's unique identifier, size, flow coefficient Kv (Cv), pressure drop at specified flow rate, spring range, positive positioner range, actuator size, close-off pressure to torque data, dimensions, and access and clearance requirements data. In the valve schedule include actuator selection data supported by calculations of the force required to move and seal the valve, access and clearance requirements. Provide a single valve schedule for the entire project.

3.2.5 Damper Schedule

Provide a damper schedule containing each damper's unique identifier, type (opposed or parallel blade), nominal and actual sizes, orientation of axis and frame, direction of blade rotation, actuator size and spring ranges, operation rate, positive positioner range, location of actuators and damper end switches, arrangement of sections in multi-section dampers, and methods of connecting dampers, actuators, and linkages. Include the AMCA 511 maximum leakage rate at the operating static-pressure differential for each damper in the Damper Schedule. Provide a single damper schedule for the entire project.

3.2.6 Project Summary Equipment Schedule

Provide a project summary equipment schedule containing the manufacturer, model number, part number and descriptive name for each control device, hardware and component provided under this specification. Provide a single project equipment schedule for the entire project.

3.2.7 Equipment Schedule

Provide system equipment schedules containing the unique identifier, manufacturer, model number, part number and descriptive name for each control device, hardware and component provided under this specification. Provide a separate equipment schedule for each HVAC system.

3.2.8 Occupancy Schedule

Provide an occupancy schedule drawing containing the same fields as the occupancy schedule Contract Drawing with Contractor updated information. Provide a single occupancy schedule for the entire project.

3.2.9 DDC Hardware Schedule

Provide a single DDC Hardware Schedule for the entire project and including following information for each device.

3.2.9.1 DDC Hardware Identifier

The Unique DDC Hardware Identifier for the device.

3.2.9.2 HVAC System

The system "name" used to identify a specific system (the name used on the system schematic drawing for that system).

3.2.9.3 BACnet Device Information

3.2.9.3.1 Device Object Identifier

The Device Object Identifier: The Object_Identifier of the Device Object

3.2.9.3.2 Network Number

The Network Number for the device.

3.2.9.3.3 MAC Address

The MAC Address for the device

3.2.9.3.4 BTL Listing

The BTL Listing of the device. If the device is listed under multiple BTL Profiles, indicate the profile that matches the use and configuration of the device as installed.

3.2.9.3.5 Proprietary Services Information

If the device uses non-standard ASHRAE 135 services as defined and permitted in Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS, indicate that the device uses non-standard services and include a description of all non-standard services used. Describe usage and content such that a device from another vendor can interoperate with the device using the non-standard service. Provide descriptions with sufficient detail to allow a device from a different manufacturer to be programmed to both read and write the non-standard service request:

- a. read: interpret the data contained in the non-standard service and;
- b. write: given similar data, generate the appropriate non-standard service request.

3.2.9.3.6 Alarming Information

Indicate whether the device is used for alarm generation, and which types of alarm generation the device implements: intrinsic, local algorithmic, remote algorithmic.

3.2.9.3.7 Scheduling Information

Indicate whether the device is used for scheduling.

3.2.9.3.8 Trending Information

Indicate whether the device is used for trending, and indicate if the device is used to trend local values, remote values, or both.

3.2.10 Points Schedule

Provide a Points Schedule in tabular form for each HVAC system, with the indicated columns and with each row representing a hardware point, network point or configuration point in the system.

- a. When a Points Schedule was included in the Contract Drawing package, use the same fields as the Contract Drawing with updated information in addition to the indicated fields.
- b. When Point Schedules are included in the contract package, items requiring contractor verification or input have been shown in angle brackets (" $<$ " and " $>$ "), such as $< ___ >$ for a required entry or $< \text{value} >$ for a value requiring confirmation. Complete all items in brackets as well as any blank cells. Do not modify values which are not in brackets without approval.

Points Schedule Columns must include:

3.2.10.1 Point Name

The abbreviated name for the point using the indicated naming convention.

3.2.10.2 Description

A brief functional description of the point such as "Supply Air Temperature".

3.2.10.3 DDC Hardware Identifier

The Unique DDC Hardware Identifier shown on the DDC Hardware Schedule and used across all drawings for the DDC Hardware containing the point.

3.2.10.4 Settings

The value and units of any setpoints, configured setpoints, configuration parameters, and settings related to each point.

3.2.10.5 Range

The range of values, including units, associated with the point, including but not limited to a zone temperature setpoint adjustment range, a sensor measurement range, occupancy values for an occupancy input, or the status of a safety.

3.2.10.6 Input or Output (I/O) Type

The type of input or output signal associated with the point. Use the following abbreviations for entries in this column:

- a. AI: The value comes from a hardware (physical) Analog Input
- b. AO: The value is output as a hardware (physical) Analog Output
- c. BI: The value comes from a hardware (physical) Binary Input
- d. BO: The value is output as a hardware (physical) Binary Output
- e. PULSE: The value comes from a hardware (physical) Pulse Accumulator Input
- f. NET-IN: The value is provided from the network (generally from another device). Use this entry only when the value is received from another device as part of scheduling or as part of a sequence of operation, not when the value is received on the network for supervisory functions such as trending, alarming, override or display at a user interface.
- g. NET-OUT: The value is provided to another controller over the network. Use this entry only when the value is transmitted to another device as part of scheduling or as part of a sequence of operation, not when the value is transmitted on the network for supervisory functions such as trending, alarming, override or display at a user interface.

3.2.10.7 Object and Property Information

The Object Type and Instance Number for the Object associated with the

point. If the value of the point is not in the Present_Value Property, then also provide the Property ID for the Property containing the value of the point. Any point that is displayed at the front end or on an LDP, is trended, is used by another device on the network, or has an alarm condition must be documented here.

3.2.10.8 Network Data Exchange Information (Gets Data From, Sends Data To)

Provide the DDC Hardware Identifier of other DDC Hardware the point is shared with.

3.2.10.9 Override Information (Object Type and Instance Number)

For each point requiring an Override, indicate if the Object for the point is Commandable or, if the use of a separate Object was specifically approved by the Contracting Officer, provide the Object Type and Instance Number of the Object to be used in overriding the point.

3.2.10.10 Trend Object Information

For each point requiring a trend, indicate if the trend is Local or Remote, the trend Object type and the trend Object instance number. For remote trends provide the DDC Hardware Identifier for the device containing the trend Object in the Points Schedule notes.

3.2.10.11 Alarm Information

Indicate the Alarm Generation Type, Event Enrollment Object Instance Number, and Notification Class Object Instance Number for each point requiring an alarm. (Note that not all alarms will have Event Enrollment Objects.)

3.2.10.12 Configuration Information

Indicate the means of configuration associated with each point.

- a. For Operator Configurable Points indicate BACnet Object and Property information (Name, Type, Identifiers) containing the configurable value. Indicate whether the property is writable always, or only when Out_Of_Service is TRUE.
- b. For Configurable Points indicate the BACnet Object and Property information as for Operator Configurable points, or identification of the configurable settings from within the engineering software for the device or identification of the hardware settings on the device.

3.2.11 Riser Diagram

The Riser Diagram of the Building Control Network may be in tabular form, and must show all DDC Hardware and all Network Hardware, including network terminators. For each item, provide the unique identifier, common descriptive name, physical sequential order (previous and next device on the network), room identifier and location within room. A single riser diagram must be submitted for the entire system.

3.2.12 Control System Schematics

Provide control system schematics in the same form as the control system schematic Contract Drawing with Contractor updated information. Provide a control system schematic for each HVAC system.

3.2.13 Sequences of Operation Including Control Logic Diagrams

Provide HVAC control system sequence of operation and control logic diagrams in the same format as the Contract Drawings. Within these drawings, refer to devices by their unique identifiers. Submit sequences of operation and control logic diagrams for each HVAC system

3.2.14 Controller, Motor Starter and Relay Wiring Diagram

Provide controller wiring diagrams as functional wiring diagrams which show the interconnection of conductors and cables to each controller and to the identified terminals of input and output devices, starters and package equipment. Show necessary jumpers and ground connections and the labels of all conductors. Identify sources of power required for control systems and for packaged equipment control systems back to the panel board circuit breaker number, controller enclosures, magnetic starter, or packaged equipment control circuit. Show each power supply and transformer not integral to a controller, starter, or packaged equipment. Show the connected volt-ampere load and the power supply volt-ampere rating. Provide wiring diagrams for each HVAC system.

3.3 CONTROLLER TUNING

Tune each controller in a manner consistent with that described in the ASHRAE FUN IP and in the manufacturer's instruction manual. Tuning must consist of adjustment of the proportional, integral, and where applicable, the derivative (PID) settings to provide stable closed-loop control. Each loop must be tuned while the system or plant is operating at a high gain (worst case) condition, where high gain can generally be defined as a low-flow or low-load condition. Upon final adjustment of the PID settings, in response to a change in controller setpoint, the controlled variable must settle out at the new setpoint with no more than two (2) oscillations above and below setpoint. Upon settling out at the new setpoint the controller output must be steady. With the exception of naturally slow processes such as zone temperature control, the controller must settle out at the new setpoint within five (5) minutes. Set the controller to its correct setpoint and record and submit the final PID configuration settings with the O&M Instructions and on the associated Points Schedule.

3.4 START-UP

3.4.1 Start-Up Test

Perform the following startup tests for each control system to ensure that the described control system components are installed and functioning per this specification.

Adjust, calibrate, measure, program, configure, set the time schedules, and otherwise perform all necessary actions to ensure that the systems function as indicated and shown in the sequence of operation and other contract documents.

3.4.1.1 Systems Check

An item-by-item check must be performed for each HVAC system

3.4.1.1.1 Step 1 - System Inspection

With the system in unoccupied mode and with fan hand-off-auto switches in the OFF position, verify that power and main air are available where required and that all output devices are in their failsafe and normal positions. Inspect each local display panel and each M&C Client to verify that all displays indicate shutdown conditions.

3.4.1.1.2 Step 2 - Calibration Accuracy Check

Perform a two-point accuracy check of the calibration of each HVAC control system sensing element and transmitter by comparing the value from the test instrument to the network value provided by the DDC Hardware. Use digital indicating test instruments, such as digital thermometers, motor-driven psychrometers, and tachometers. Use test instruments with accuracy at least twice as accurate as the specified sensor accuracy and with calibration traceable to National Institute of Standards and Technology standards. Check one the first check point in the bottom one-third of the sensor range, and the second in the top one-third of the sensor range. Verify that the sensing element-to-DDC readout accuracies at two points are within the specified product accuracy tolerances, and if not recalibrate or replace the device and repeat the calibration check.

3.4.1.1.3 Step 3 - Actuator Range Check

With the system running, apply a signal to each actuator through the DDC Hardware controller. Verify proper operation of the actuators and positioners for all actuated devices and record the signal levels for the extreme positions of each device. Vary the signal over its full range, and verify that the actuators travel from zero stroke to full stroke within the signal range. Where applicable, verify that all sequenced actuators move from zero stroke to full stroke in the proper direction, and move the connected device in the proper direction from one extreme position to the other. For valve actuators and damper actuators, perform the actuator range check under normal system pressures.

3.4.1.2 Weather Dependent Test

Perform weather dependent test procedures in the appropriate climatic season.

3.4.2 Start-Up Testing Report

Submit 4 copies of the Start-Up Testing Report. The report may be submitted as a Technical Data Package documenting the results of the tests performed and certifying that the system is installed and functioning per this specification, and is ready for the Performance Verification Test (PVT).

3.5 PERFORMANCE VERIFICATION TEST (PVT)

3.5.1 PVT Procedures

Prepare PVT Procedures based on Section 25 08 10 UTILITY MONITORING AND CONTROL SYSTEM TESTING explaining step-by-step, the actions and expected results that will demonstrate that the control system performs in accordance with the sequences of operation, and other contract documents. Submit 4 copies of the PVT Procedures. The PVT Procedures may be submitted as a Technical Data Package.

3.5.1.1 Sensor Accuracy Checks

Include a one-point accuracy check of each sensor in the PVT procedures.

3.5.1.2 Endurance Test

Include a one-week endurance test as part of the PVT during which the system is operated continuously.

Use the building control system BACnet Trend Log or Trend Log Multiple Objects to trend all points shown as requiring a trend on the Point Schedule for the entire endurance test. If insufficient buffer capacity exists to trend the entire endurance test, upload trend logs during the course of the endurance test to ensure that no trend data is lost.

3.5.1.3 PVT Equipment List

Include in the PVT procedures a control system performance verification test equipment list that lists the equipment to be used during performance verification testing. For each piece of equipment, include manufacturer name, model number, equipment function, the date of the latest calibration, and the results of the latest calibration

3.5.2 PVT Execution

Demonstrate compliance of the control system with the contract documents. Using test plans and procedures approved by the Government, software capable of reading and writing COV Notification Subscriptions, Notification Class Recipient List Properties, event enrollments, demonstrate all physical and functional requirements of the project. Show, step-by-step, the actions and results demonstrating that the control systems perform in accordance with the sequences of operation. Do not start the performance verification test until after receipt of written permission by the Government, based on Government approval of the PVT Plan and Draft As-Builts and completion of balancing. UNLESS GOVERNMENT WITNESSING OF A TEST IS SPECIFICALLY WAIVED BY THE GOVERNMENT, PERFORM ALL TESTS WITH A GOVERNMENT WITNESS. Do not conduct tests during scheduled seasonal off periods of base heating and cooling systems. If the system experiences any failures during the endurance test portion of the PVT, repair the system repeat the endurance test portion of the PVT until the system operates continuously and without failure for the specified endurance test period.

3.5.3 PVT Report

Prepare and submit a PVT report documenting all tests performed during the PVT and their results. Include all tests in the PVT procedures and any additional tests performed during PVT. Document test failures and repairs conducted with the test results.

Submit four copies of the PVT Report. The PVT Report may be submitted as a Technical Data Package.

3.6 OPERATION AND MAINTENANCE (O&M) INSTRUCTIONS

Provide HVAC control System Operation and Maintenance Instructions which include:

- a. "Data Package 3" as indicated in Section 01 78 23 OPERATION AND MAINTENANCE DATA for each piece of control equipment.
- b. "Data Package 4" as described in Section 01 78 23 OPERATION AND MAINTENANCE DATA for all air compressors.
- c. HVAC control system sequences of operation formatted as indicated.
- d. Procedures for the HVAC system start-up, operation and shut-down including the manufacturer's supplied procedures for each piece of equipment, and procedures for the overall HVAC system.
- e. As-built HVAC control system detail drawings formatted as indicated.
- f. Routine maintenance checklist. Provide the routine maintenance checklist arranged in a columnar format, where the first column lists all installed devices, the second column states the maintenance activity or that no maintenance required, the third column states the frequency of the maintenance activity, and the fourth column is used for additional comments or reference.
- g. Qualified service organization list, including at a minimum company name, contact name and phone number.
- h. Start-Up Testing Report.
- i. Performance Verification Test (PVT) Procedures and Report.

Submit 2 copies of the Operation and Maintenance Instructions, indexed and in booklet form. The Operation and Maintenance Instructions may be submitted as a Technical Data Package.

3.7 TRAINING

Conduct a training course for operating staff members designated by the Government in the maintenance and operation of the system, including specified hardware and software. Conduct 32 hours of training at the project site within 30 days after successful completion of the performance verification test. The Government reserves the right to make audio and visual recordings (using Government supplied equipment) of the training sessions for later use. Provide audiovisual equipment and other training materials and supplies required to conduct training. A training day is

defined as 8 hours of classroom instruction, including two 15 minute breaks and excluding lunchtime, Monday through Friday, during the daytime shift in effect at the training facility.

3.7.1 Training Documentation

Prepare training documentation consisting of:

- a. Course Attendee List: Develop the list of course attendees in coordination with and signed by the Controls shop supervisor.
- b. Training Manuals: Provide training manuals which include an agenda, defined objectives for each lesson, and a detailed description of the subject matter for each lesson. When presenting portions of the course material by audiovisuals, deliver copies of those audiovisuals as a part of the printed training manuals.

3.7.2 Training Course Content

For guidance in planning the required instruction, assume that attendees will have a high school education, and are familiar with HVAC systems. During the training course, cover all of the material contained in the Operating and Maintenance Instructions, the layout and location of each controller enclosure, the layout of one of each type of equipment and the locations of each, the location of each control device external to the panels, the location of the compressed air station, preventive maintenance, troubleshooting, diagnostics, calibration, adjustment, commissioning, tuning, and repair procedures. Typical systems and similar systems may be treated as a group, with instruction on the physical layout of one such system. Present the results of the performance verification test and the Start-Up Testing Report as benchmarks of HVAC control system performance by which to measure operation and maintenance effectiveness.

3.7.3 Training Documentation Submittal Requirements

Submit hardcopy training manuals and all training materials on CD-ROM. Provide one hardcopy manual for each trainee on the Course Attendee List and 2 additional copies for archive at the project site. Provide 2 copies of the Course Attendee List with the archival copies. Training Documentation may be submitted as a Technical Data Package.

APPENDIX A

<u>QC CHECKLIST FOR BACNET SYSTEMS</u>		
<p>This checklist is not all-inclusive of the requirements of this specification and should not be interpreted as such.</p> <p>Instructions: Initial each item in the space provided (____) verifying that the requirement has been met.</p>		
<p>This checklist is for (circle one:)</p> <p style="padding-left: 40px;">Pre-Construction QC Checklist Submittal</p> <p style="padding-left: 40px;">Post-Construction QC Checklist Submittal</p> <p style="padding-left: 40px;">Close-out QC Checklist Submittal</p>		
<p>Items verified for Pre-Construction, Post-Construction and Closeout QC Checklist Submittals:</p>		
1	All DDC Hardware is numbered on Control System Schematic Drawings.	____
2	Signal lines on Control System Schematic are labeled with the signal type.	____
3	Local Display Panel (LDP) Locations are shown on Control System Schematic drawings.	____
<p>Items verified for Post-Construction and Closeout QC Checklist Submittals:</p>		
4	All sequences are performed as specified using DDC Hardware.	____
5	Training schedule and course attendee list has been developed and coordinated with shops and submitted.	____
<p>Items verified for Closeout QC Checklist Submittal:</p>		
6	Final As-built Drawings, including all Points Schedule drawings, accurately represent the final installed system.	____
7	Programming software has been submitted for all programmable controllers.	____
8	All software has been licensed to the Government.	____

<u>QC CHECKLIST FOR BACNET SYSTEMS</u>		
9	O&M Instructions have been completed and submitted.	___
10	Training course has been completed.	___
11	All DDC Hardware is installed on a BACnet ASHRAE 135 network using either MS/TP in accordance with Clause 9 or IP in accordance with Annex J.	___
12	All DDC Hardware is BTL listed.	___
13	Communication between DDC Hardware is only via BACnet using standard services, except as specifically permitted by the specification. Non-standard services have been fully documented in the DDC Hardware Schedule.	___
14	Scheduling, Alarming, and Trending have been implemented using the standard BACnet Objects for these functions.	___
15	All Properties indicated as required to be Writable are Writable and Overrides have been provided as indicated	___
<div style="display: flex; justify-content: space-between; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;"> </div>		
	(QC Representative Signature)	(Date)

-- End of Section --

SECTION 23 09 13.34 40

CONTROL VALVES, SELF-CONTAINED
02/17

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B16.1 (2020) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250

ASTM INTERNATIONAL (ASTM)

ASTM A48/A48M (2003; R 2021) Standard Specification for Gray Iron Castings

ASTM B61 (2015; R 2021) Standard Specification for Steam or Valve Bronze Castings

1.2 ADMINISTRATIVE REQUIREMENTS

Section 23 30 00 HVAC AIR DISTRIBUTION applies to work specified in this section.

Submit fabrication drawings for self-contained control and relief valves, including part numbers and exploded views.

Submit a list of product installations for self-contained control and relief valves, identifying a minimum of five installed units, similar to those proposed for use, that have been in successful service for a minimum period of 5 years.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Fabrication Drawings; G

Installation Drawings; G

SD-03 Product Data

Self-Contained Temperature Control Valves; G

Self-Contained Temperature-Regulator Valves; G

Pilot-Operated Pressure Relief Valve; G

Sample Warranty; G

SD-07 Certificates

List of Product Installations; G

Certificates of Conformance; G

Manufacturer's Warranty; G

SD-06 Test Reports

Test Reports; G

1.4 QUALITY ASSURANCE

Submit certificates of conformance for the following items, showing conformance with the referenced standards contained in this section:

- a. Self-Contained Temperature Control Valves
- b. Self-Contained Temperature Regulator Valves
- c. Rate-of-Flow Controller
- d. Nonmodulating Float Valve
- e. Water Pressure Regulating Valve
- f. Water Pressure Relief Valve
- g. Pilot-Operated Pressure Relief Valve
- 3 h. Relief Valves for Electric Water Heaters

Submit a copy of the manufacturer's sample warranty to the Contracting Officer for review.

PART 2 PRODUCTS

2.1 SELF-CONTAINED TEMPERATURE-CONTROL VALVES

Provide self-contained temperature-control valves that meet the following requirements:

- a. Type I, Class II (integral temperature-sensing units for very hot water).

Mount the set-point adjustment on the cabinet of the convector; ensure

that the control knob is accessible on the cabinet surface.

Wall-mount the set-point adjustment and thermostat for finned-tube radiation. Provide nickel-plated brass thermostat surfaces.

Provide armored capillary tubing, with the remote element at least 18 inches long and contained within a guard.

Provide renewable valve disks.

2.2 SELF-CONTAINED TEMPERATURE-REGULATOR VALVES

Provide direct-operated, self-contained valves, with an ASTM B61, (bronze) body rated not less than 125 pounds per square inch (psi) of saturated working steam pressure. Provide with screwed body end connections. Ensure that the trim is corrosion-resistant AISI Type 300 Series steel. Provide valves that have a hardened replaceable seat and plug, or faced with a cobalt-chromium-tungsten alloy to produce a surface with resistance to impact and wire-drawing and with a Brinell hardness of at least 450. Fit packed steam valves with tetrafluoroethylene packing, and spring-load and self-adjust. Ensure that the valves are single-seated, suitable for dead-end service, and fail-safe. Mount a remote Class I or Class III filled-bulb element in a nonferrous separable socket. Ensure that valves maintain the set-point temperature, plus or minus 5 degrees F, with the set point at or near the midpoint of the adjustable element range.

2.3 PILOT-OPERATED PRESSURE-RELIEF VALVE

Provide a pilot-operated pressure-relief valve that is hydraulically operated and has pilot-controlled modulating, with an adjustable set point over the indicated range. Provide a cast-iron valve body conforming to ASTM A48/A48M, with 125 psi ASME B16.1 flanges. Include the with manufacturer's standard brass, bronze, or corrosion-resistant steel valve trim. Provide pilot control with AISI Type 303 or 304 corrosion-resistant steel trim with Buna-N diaphragm and seal material. Ensure that this valve has a maximum-service-pressure rating of at least 175 psi at 180 degrees F.

PART 3 EXECUTION

3.1 INSTALLATION

Submit installation drawings for self-contained control and relief valves. Install valves as specified in accordance with the manufacturer's recommendations and Section 23 05 15 COMMON PIPING FOR HVAC.

3.2 FIELD QUALITY CONTROL

3.2.1 Test Reports

After the installation has been completed, test the system components and submit 2 copies of the test reports to the Contracting Officer. Remove and replace defective components at no cost to the Government. Retest components and submit reports to the Contracting Officer.

3.3 CLOSEOUT ACTIVITIES

Submit 2 copies of the manufacturer's warranty, to the Contracting Officer

before project closeout. Ensure that the warranty has been signed by the Authority Having Jurisdiction (AHJ) and is assigned to the Government.

-- End of Section --

SECTION 23 09 13

INSTRUMENTATION AND CONTROL DEVICES FOR HVAC
11/15, CHG 2: 05/21

PART 1 GENERAL

1.1 SUMMARY

This section provides for the instrumentation control system components excluding direct digital controllers, network controllers, gateways etc. that are necessary for a completely functional automatic control system. When combined with a Direct Digital Control (DDC) system, the Instrumentation and Control Devices covered under this section must be a complete system suitable for the control of the heating, ventilating and air conditioning (HVAC) and other building-level systems as specified and indicated.

- a. Install hardware to perform the control sequences as specified and indicated and to provide control of the equipment as specified and indicated.
- b. Install hardware such that individual control equipment can be replaced by similar control equipment from other equipment manufacturers with no loss of system functionality.
- c. Install and configure hardware such that the Government or their agents are able to perform repair, replacement, and upgrades of individual hardware without further interaction with the installing Contractor.

1.1.1 Verification of Dimensions

After becoming familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before performing any work.

1.1.2 Drawings

The Government will not indicate all offsets, fittings, and accessories that may be required on the drawings. Carefully investigate the mechanical, electrical, and finish conditions that could affect the work to be performed, arrange such work accordingly, and provide all work necessary to meet such conditions.

1.2 RELATED SECTIONS

Related work specified elsewhere.

Section 01 30 00 ADMINISTRATIVE REQUIREMENTS

Section 23 30 00 HVAC AIR DISTRIBUTION

Section 23 05 15 COMMON PIPING FOR HVAC

Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC

Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM

1.3 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC. (AMCA)

- AMCA 500-D (2018) Laboratory Methods of Testing Dampers for Rating
- AMCA 511 (2010; R 2016) Certified Ratings Program for Air Control Devices

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

- ANSI C12.1 (2014; Errata 2016) Electric Meters - Code for Electricity Metering

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

- ASME B16.15 (2018) Cast Copper Alloy Threaded Fittings Classes 125 and 250
- ASME B16.34 (2021) Valves - Flanged, Threaded and Welding End
- ASME BPVC SEC VIII D1 (2019) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1

ASTM INTERNATIONAL (ASTM)

- ASTM A536 (1984; R 2019; E 2019) Standard Specification for Ductile Iron Castings

FLUID CONTROLS INSTITUTE (FCI)

- FCI 70-2 (2021) Control Valve Seat Leakage

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

- IEEE 142 (2007; Errata 2014) Recommended Practice for Grounding of Industrial and Commercial Power Systems - IEEE Green Book

INTERNATIONAL SOCIETY OF AUTOMATION (ISA)

- ISA 7.0.01 (1996) Quality Standard for Instrument Air

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

- ANSI C12.20 (2015; E 2018) Electricity Meters - 0.1, 0.2, and 0.5 Accuracy Classes
- NEMA 250 (2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
- NEMA/ANSI C12.10 (2011; R 2021) Physical Aspects of

Watt-hour Meters - Safety Standard

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code
- NFPA 90A (2024) Standard for the Installation of Air Conditioning and Ventilating Systems

UNDERWRITERS LABORATORIES (UL)

- UL 555 (2006; Reprint Aug 2016) UL Standard for Safety Fire Dampers
- UL 555S (2014; Reprint Oct 2020) UL Standard for Safety Smoke Dampers
- UL 5085-3 (2006; Reprint Jan 2022) UL Standard for Safety Low Voltage Transformers - Part 3: Class 2 and Class 3 Transformers

1.4 SUBMITTALS

Submittal requirements are specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

1.5 DELIVERY AND STORAGE

Store and protect products from the weather, humidity, and temperature variations, dirt and dust, and other contaminants, within the storage condition limits published by the equipment manufacturer.

1.6 INPUT MEASUREMENT ACCURACY

Select, install and configure sensors, transmitters and DDC Hardware such that the maximum error of the measured value at the input of the DDC hardware is less than the maximum allowable error specified for the sensor or instrumentation.

1.7 SUBCONTRACTOR SPECIAL REQUIREMENTS

Perform all work in this section in accordance with the paragraph entitled CONTRACTOR SPECIAL REQUIREMENTS in Section 01 30 00 ADMINISTRATIVE REQUIREMENTS.

PART 2 PRODUCTS

2.1 EQUIPMENT

2.1.1 General Requirements

All products used to meet this specification must meet the indicated requirements, but not all products specified here will be required by every project. All products must meet the requirements both Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and this Section.

2.1.2 Operation Environment Requirements

Unless otherwise specified, provide products rated for continuous operation under the following conditions:

2.1.2.1 Pressure

Pressure conditions normally encountered in the installed location.

2.1.2.2 Vibration

Vibration conditions normally encountered in the installed location.

2.1.2.3 Temperature

- a. Products installed indoors: Ambient temperatures in the range of 32 to 112 degrees F and temperature conditions outside this range normally encountered at the installed location.
- b. Products installed outdoors or in unconditioned indoor spaces: Ambient temperatures in the range of -35 to +151 degrees F and temperature conditions outside this range normally encountered at the installed location.

2.1.2.4 Humidity

10 to 95 percent relative humidity, non-condensing and also humidity conditions outside this range normally encountered at the installed location.

2.2 WEATHERSHIELDS

Provide weathershields constructed of galvanized steel painted white, unpainted aluminum, aluminum painted white, or white PVC.

2.3 WIRE AND CABLE

Provide wire and cable meeting the requirements of NFPA 70 and NFPA 90A in addition to the requirements of this specification and referenced specifications.

2.3.1 Terminal Blocks

For terminal blocks which are not integral to other equipment, provide terminal blocks which are insulated, modular, feed-through, clamp style with recessed captive screw-type clamping mechanism, suitable for DIN rail mounting, and which have enclosed sides or end plates and partition plates for separation.

2.3.2 Control Wiring for Binary Signals

For Control Wiring for Binary Signals, provide 18 AWG copper or thicker wire rated for 300-volt service.

2.3.3 Control Wiring for Analog Signals

For Control Wiring for Analog Signals, provide 18 AWG or thicker, copper, single- or multiple-twisted wire meeting the following requirements:

- a. minimum 2 inch lay of twist
- b. 100 percent shielded pairs
- c. at least 300-volt insulation
- d. each pair has a 20 AWG tinned-copper drain wire and individual overall pair insulation
- e. cables have an overall aluminum-polyester or tinned-copper cable-shield tape, overall 20 AWG tinned-copper cable drain wire, and overall cable insulation.

2.3.4 Power Wiring for Control Devices

For 24-volt circuits, provide insulated copper 18 AWG or thicker wire rated for 300 VAC service. For 120-volt circuits, provide 14 AWG or thicker stranded copper wire rated for 600-volt service.

2.3.5 Transformers

Provide UL 5085-3 approved transformers. Select transformers sized so that the connected load is no greater than 80 percent of the transformer rated capacity.

2.4 AUTOMATIC CONTROL VALVES

Provide valves with stainless-steel stems and stuffing boxes with extended necks to clear the piping insulation. Provide valves with bodies meeting ASME B16.34 or ASME B16.15 pressure and temperature class ratings based on the design operating temperature and 150 percent of the system design operating pressure. Unless otherwise specified or indicated, provide valves meeting FCI 70-2 Class III leakage rating. Provide valves rated for modulating or two-position service as indicated, which close against a differential pressure indicated as the Close-Off pressure and which are Normally-Open, Normally-Closed, or Fail-In-Last-Position as indicated.

2.4.1 Valve Type

2.4.1.1 Liquid Service 150 Degrees F or Less

Use either globe valves or ball valves except that butterfly valves may be used for sizes 4 inch and larger.

2.4.1.2 Liquid Service Above 150 Degrees F

- a. Two-position valves: Use either globe valves or ball valves except that butterfly valves may be used for sizes 4 inch and larger.
- b. Modulating valves: Use globe valves except that butterfly valves may be used for sizes 4 inch and larger.

2.4.1.3 Steam Service

Use globe valves except that butterfly valves may be used for sizes 4 inch and larger.

2.4.2 Valve Flow Coefficient and Flow Characteristic

2.4.2.1 Two-Way Modulating Valves

Provide the valve coefficient (Cv) indicated. Provide equal-percentage flow characteristic for liquid service except for butterfly valves. Provide linear flow characteristic for steam service except for butterfly valves.

2.4.2.2 Three-Way Modulating Valves

Provide the valve coefficient (Cv) indicated. Provide linear flow characteristic with constant total flow throughout full plug travel.

2.4.3 Two-Position Valves

Use full line size full port valves with maximum available (Cv).

2.4.4 Globe Valves

2.4.4.1 Liquid Service Not Exceeding 150 Degrees F

- a. Valve body and body connections:
 - (1) valves 1-1/2 inches and smaller: brass or bronze body, with threaded or union ends
 - (2) valves from 2 inches to 3 inches inclusive: brass, bronze, or iron bodies. 2 inch valves with threaded connections; 2-1/2 to 3 inches valves with flanged connections
- b. Internal valve trim: Brass or bronze.
- c. Stems: Stainless steel.
- d. Provide valves compatible with a solution of 50 percent ethylene or propylene glycol.

2.4.4.2 Liquid Service Not Exceeding 250 Degrees F

- a. Valve body and body connections:
 - (1) valves 1-1/2 inches and smaller: brass or bronze body, with threaded or union ends
 - (2) valves from 2 inches to 3 inches inclusive: brass, bronze, or iron bodies. 2 inch valves with threaded connections; 2-1/2 to 3 inches valves with flanged connections
- b. Internal trim: Type 316 stainless steel including seats, seat rings, modulation plugs, valve stems, and springs.
- c. Provide valves with non-metallic parts suitable for a minimum continuous operating temperature of 250 degrees F or 50 degrees F above the system design temperature, whichever is higher.
- d. Provide valves compatible with a solution of 50 percent ethylene or propylene glycol

2.4.4.3 Hot water service 250 Degrees F and above

- a. Provide valve bodies conforming to ASME B16.34 Class 300. For valves 1 inch and larger provide valves with bodies which are carbon steel, globe type with welded ends. For valves smaller than 1 inch provide valves with socket-weld ends. Provide valves with virgin polytetrafluoroethylene (PTFE) packing. Provide valve and actuator combinations which are normally closed.
- b. Internal trim: Type 316 stainless steel including seats, seat rings, modulation plugs, valve stems, and springs.

2.4.4.4 Steam Service

For steam service, provide valves meeting the following requirements:

- a. Valve body and connections:
 - (1) valves 1-1/2 inches and smaller: complete body of brass or bronze, with threaded or union ends
 - (2) valves from 2 inches to 3 inches inclusive: body of brass, bronze, or carbon steel
 - (3) valves 4 inches and larger: body of carbon steel. 2 inch valves with threaded connections; valves 2-1/2 inches and larger with flanged connections.
- b. Internal Trim: Type 316 stainless steel including seats, seat rings, modulation plugs, valve stems, and springs.
- c. Valve sizing: sized for 15 psig inlet steam pressure with a maximum 12 psi differential through the valve at rated flow, except where indicated otherwise.

2.4.5 Ball Valves

2.4.5.1 Liquid Service Not Exceeding 150 Degrees F

- a. Valve body and connections:
 - (1) valves 1-1/2 inches and smaller: bodies of brass or bronze, with threaded or union ends
 - (2) valves from 2 inches to 3 inches inclusive: bodies of brass, bronze, or iron. 2 inch valves with threaded connections; valves from 2-1/2 to 3 inches with flanged connections.
- b. Ball: Stainless steel or nickel-plated brass or chrome-plated brass.
- c. Seals: Reinforced Teflon seals and EPDM O-rings.
- d. Stem: Stainless steel, blow-out proof.
- e. Provide valves compatible with a solution of 50 percent ethylene or propylene glycol.

2.4.6 Butterfly Valves

Provide butterfly valves which are threaded lug type suitable for dead-end service and modulation to the fully-closed position, with carbon-steel bodies or with ductile iron bodies in accordance with ASTM A536. Provide butterfly valves with non-corrosive discs, stainless steel shafts supported by bearings, and EPDM seats suitable for temperatures from -20 to +250 degrees F. Provide valves with rated Cv of the Cv at 70 percent (60 degrees) open position. Provide valves meeting FCI 70-2 Class VI leakage rating.

2.4.7 Pressure Independent Control Valves (PICV)

Provide pressure independent control valves which include a regulator valve which maintains the differential pressure across a flow control valve. Pressure independent control valves must accurately control the flow from 0-100 percent full rated flow regardless of changes in the piping pressure and not vary the flow more than plus or minus 5 percent at any given flow control valve position when the PICV differential pressure lies between the manufacturer's stated minimum and maximum. The rated minimum differential pressure for steady flow must not exceed 5 psid across the PICV. Provide either globe or ball type valves meeting the indicated requirements for globe and ball valves. Provide valves with a flow tag listing full rated flow and minimum required pressure drop. Provide valves with factory installed Pressure/Temperature ports ("Pete's Plugs") to measure the pressure drop to determine the valve flow rate.

2.4.8 Duct-Coil and Terminal-Unit-Coil Valves

For duct or terminal-unit coils provide control valves with either flare-type or solder-type ends. Provide flare nuts for each flare-type end valve.

2.5 DAMPERS

2.5.1 Damper Assembly

Provide single damper sections with blades no longer than 48 inches and which are no higher than 72 inches and damper blade width of 8 inches or less. When larger sizes are required, combine damper sections. Provide dampers made of steel, or other materials where indicated and with assembly frames constructed of 0.07 inch minimum thickness stainless steel channels with mitered and welded corners. Steel channel frames constructed of 0.06 inch minimum thickness are acceptable provided the corners are reinforced.

- a. Flat blades must be made rigid by folding the edges. Blade-operating linkages must be within the frame so that blade-connecting devices within the same damper section must not be located directly in the air stream.
- b. Damper axles must be 1/2 inch minimum, plated steel rods supported in the damper frame by stainless steel or bronze bearings. Blades mounted vertically must be supported by thrust bearings.
- c. Provide dampers which do not exceed a pressure drop through the damper of 0.04 inches water gauge at 1000 ft/min in the wide-open position. Provide dampers with frames not less than 2 inch in width. Provide dampers which have been tested in accordance with AMCA 500-D.

2.5.2 Operating Linkages

For operating links external to dampers, such as crank arms, connecting rods, and line shafting for transmitting motion from damper actuators to dampers, provide links able to withstand a load equal to at least 300 percent of the maximum required damper-operating force without deforming. Rod lengths must be adjustable. Links must be brass, bronze, zinc-coated steel, or stainless steel. Working parts of joints and clevises must be brass, bronze, or stainless steel. Adjustments of crank arms must control the open and closed positions of dampers.

2.5.3 Damper Types

2.5.3.1 Flow Control Dampers

Provide parallel-blade or opposed blade type dampers for outside air, return air, relief air, exhaust, face and bypass dampers as indicated on the Damper Schedule. Blades must have interlocking edges. The channel frames of the dampers must be provided with jamb seals to minimize air leakage. Unless otherwise indicated, dampers must meet AMCA 511 Class 1A requirements. Outside air damper seals must be suitable for an operating temperature range of -40 to +167 degrees F. Dampers must be rated at not less than 2000 ft/min air velocity.

2.5.3.2 Mechanical Rooms and Other Utility Space Ventilation Dampers

Provide utility space ventilation dampers as indicated. Unless otherwise indicated provide AMCA 511 class 3 dampers. Provide dampers rated at not less than 1500 ft/min air velocity.

2.5.3.3 Smoke Dampers

Provide smoke-damper and actuator assemblies which meet the current requirements of NFPA 90A, UL 555, and UL 555S. For combination fire and smoke dampers provide dampers rated for 250 degrees F Class II leakage per UL 555S.

2.6 SENSORS AND INSTRUMENTATION

Unless otherwise specified, provide sensors and instrumentation which incorporate an integral transmitter. Sensors and instrumentation, including their transmitters, must meet the specified accuracy and drift requirements at the input of the connected DDC Hardware's analog-to-digital conversion.

2.6.1 Analog and Binary Transmitters

Provide transmitters which match the characteristics of the sensor. Transmitters providing analog values must produce a linear 4-20 mAdc, 0-10 Vdc signal corresponding to the required operating range and must have zero and span adjustment. Transmitters providing binary values must have dry contacts rated at 1A at 24 Volts AC.

2.6.2 Network Transmitters

Sensors and Instrumentation incorporating an integral network connection are considered DDC Hardware and must meet the DDC Hardware requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER

BUILDING CONTROL SYSTEMS when used in a BACnet network.

2.6.3 Temperature Sensors

Provide the same sensor type throughout the project. Temperature sensors may be provided without transmitters. Where transmitters are used, the range must be the smallest available from the manufacturer and suitable for the application such that the range encompasses the expected range of temperatures to be measured. The end to end accuracy includes the combined effect of sensitivity, hysteresis, linearity and repeatability between the measured variable and the end user interface (graphic presentation) including transmitters if used.

2.6.3.1 Sensor Accuracy and Stability of Control

2.6.3.1.1 Conditioned Space Temperature

Plus or minus 0.5 degree F over the operating range.

2.6.3.1.2 Unconditioned Space Temperature

- a. Plus or minus 1 degree F over the range of 30 to 131 degrees F AND
- b. Plus or minus 4 degrees F over the rest of the operating range.

2.6.3.1.3 Duct Temperature

Plus or minus 0.5 degree F

2.6.3.1.4 Outside Air Temperature

- a. Plus or minus 2 degrees F over the range of -30 to +130 degrees F AND
- b. Plus or minus 1 degree F over the range of 30 to 130 degrees F.

2.6.3.1.5 High Temperature Hot Water

Plus or minus 3.6 degrees F.

2.6.3.1.6 Chilled Water

Plus or minus 0.8 degrees F over the range of 35 to 65 degrees F.

2.6.3.1.7 Dual Temperature Water

Plus or minus 2 degrees F.

2.6.3.1.8 Heating Hot Water

Plus or minus 2 degrees F.

2.6.3.1.9 Condenser Water

Plus or minus 2 degrees F.

2.6.3.2 Transmitter Drift

The maximum allowable transmitter drift: 0.25 degrees F per year.

2.6.3.3 Point Temperature Sensors

Point Sensors must be encapsulated in epoxy, series 300 stainless steel, anodized aluminum, or copper.

2.6.3.4 Temperature Sensor Details

2.6.3.4.1 Room Type

Provide the sensing element components within a decorative protective cover suitable for surrounding decor.

2.6.3.4.2 Duct Probe Type

Ensure the probe is long enough to properly sense the air stream temperature.

2.6.3.4.3 Duct Averaging Type

Continuous averaging sensors must be one foot in length for each 1 square foot of duct cross-sectional area, and a minimum length of 5 feet.

2.6.3.4.4 Pipe Immersion Type

For pipes with larger than 3 inch diameter, provide minimum 3 inch immersion. For pipes with less than 3 inch diameter, provide immersion at least half the diameter of the pipe. Provide each sensor with a corresponding pipe-mounted sensor well, unless indicated otherwise. Sensor wells must be stainless steel when used in steel piping, and brass when used in copper piping.

2.6.3.4.5 Outside Air Type

Provide the sensing element rated for outdoor use

2.6.4 Relative Humidity Sensor

Relative humidity sensors must use bulk polymer resistive or thin film capacitive type non-saturating sensing elements capable of withstanding a saturated condition without permanently affecting calibration or sustaining damage. The sensors must include removable protective membrane filters. Where required for exterior installation, sensors must be capable of surviving below freezing temperatures and direct contact with moisture without affecting sensor calibration. When used indoors, the sensor must be capable of being exposed to a condensing air stream (100 percent relative humidity) with no adverse effect to the sensor's calibration or other harm to the instrument. The sensor must be of the wall-mounted or duct-mounted type, as required by the application, and must be provided with any required accessories. Sensors used in duct high-limit applications must have a bulk polymer resistive sensing element. Duct-mounted sensors must be provided with a duct probe designed to protect the sensing element from dust accumulation and mechanical damage. Relative humidity (RH) sensors must measure relative humidity over a range of 0 percent to 100 percent with an accuracy of plus or minus 2 percent. RH sensors must function over a temperature range of 40 to 135 degrees F and must not drift more than 1 percent per year.

2.6.5 Carbon Dioxide (CO₂) Sensors

Provide photometric type CO₂ sensors with integral transducers and linear output. Carbon dioxide (CO₂) sensors must measure CO₂ concentrations between 0 to 2000 parts per million (ppm) using non-dispersible infrared (NDIR) technology with an accuracy of plus or minus 50 ppm and a maximum response time of 1 minute. The sensor must be rated for operation at ambient air temperatures within the range of 32 to 122 degrees F and relative humidity within the range of 20 to 95 percent (non-condensing). The sensor must have a maximum drift of 2 percent per year. The sensor chamber must be manufactured with a non-corrosive material that does not affect carbon dioxide sample concentration. Duct mounted sensors must be provided with a duct probe designed to protect the sensing element from dust accumulation and mechanical damage. The sensor must have a calibration interval no less than 5 years.

2.6.6 Differential Pressure Instrumentation

2.6.6.1 Differential Pressure Sensors

Provide Differential Pressure Sensors with ranges as indicated or as required for the application. Pressure sensor ranges must not exceed the high end range indicated on the Points Schedule by more than 50 percent. The over pressure rating must be a minimum of 150 percent of the highest design pressure of either input to the sensor. The accuracy must be plus or minus 1 percent of full scale. The sensor must have a maximum drift of 2 percent per year

2.6.6.2 Differential Pressure Switch

Provide differential pressure switches with a user-adjustable setpoint which are sized for the application such that the setpoint is between 25 percent and 75 percent of the full range. The over pressure rating must be a minimum of 150 percent of the highest design pressure of either input to the sensor. The switch must have two sets of contacts and each contact must have a rating greater than it's connected load. Contacts must open or close upon rise of pressure above the setpoint or drop of pressure below the setpoint as indicated.

2.6.7 Flow Sensors

2.6.7.1 Airflow Measurement Array (AFMA)

2.6.7.1.1 Airflow Straightener

Provide AFMAs which contain an airflow straightener if required by the AFMA manufacturer's published installation instructions. The straightener must be contained inside a flanged sheet metal casing, with the AFMA located as specified according to the published recommendation of the AFMA manufacturer. In the absence of published documentation, provide airflow straighteners if there is any duct obstruction within 5 duct diameters upstream of the AFMA. Air-flow straighteners, where required, must be constructed of 0.125 inch aluminum honeycomb and the depth of the straightener must not be less than 1.5 inches.

2.6.7.1.2 Resistance to Airflow

The resistance to air flow through the AFMA, including the airflow straightener must not exceed 0.085 inch water gauge at an airflow of 2,000

fpm. AFMA construction must be suitable for operation at airflows of up to 5000 fpm over a temperature range of 40 to 120 degrees F.

2.6.7.1.3 Outside Air Temperature

In outside air measurement or in low-temperature air delivery applications, provide an AFMA certified by the manufacturer to be accurate as specified over a temperature range of -20 to +120 degrees F .

2.6.7.1.4 Pitot Tube AFMA

Each Pitot Tube AFMA must contain an array of velocity sensing elements. The velocity sensing elements must be of the multiple pitot tube type with averaging manifolds. The sensing elements must be distributed across the duct cross section in the quantity and pattern specified or recommended by the published installation instructions of the AFMA manufacturer.

- a. Pitot Tube AFMAs for use in airflows over 600 fpm must have an accuracy of plus or minus 5 percent over a range of 500 to 2500 fpm.
- b. Pitot Tube AFMAs for use in airflows under 600 fpm must have an accuracy of plus or minus 5 percent over a range of 125 to 2500 fpm.

2.6.7.1.5 Electronic AFMA

Each electronic AFMA must consist of an array of velocity sensing elements of the resistance temperature detector (RTD) or thermistor type. The sensing elements must be distributed across the duct cross section in the quantity and pattern specified or recommended by the published application data of the AFMA manufacturer. Electronic AFMAs must have an accuracy of plus or minus 5 percent over a range of 125 to 5,000 fpm and the output must be temperature compensated over a range of 32 to 212 degrees F.

2.6.7.1.6 Fan Inlet Measurement Devices

Fan inlet measurement devices cannot be used unless indicated on the drawings or schedules.

2.6.7.2 Orifice Plate

Orifice plate must be made of an austenitic stainless steel sheet of 0.125 inch nominal thickness with an accuracy of plus or minus 1 percent of full flow. The orifice plate must be flat within 0.002 inches. The orifice surface roughness must not exceed 20 micro-inches. The thickness of the cylindrical face of the orifice must not exceed 2 percent of the pipe inside diameter or 12.5 percent of the orifice diameter, whichever is smaller. The upstream edge of the orifice must be square and sharp. Where orifice plates are used, concentric orifice plates must be used in all applications except steam flow measurement in horizontal pipelines.

2.6.7.3 Flow Nozzle

Flow nozzle must be made of austenitic stainless steel with an accuracy of plus or minus 1 percent of full flow. The inlet nozzle form must be elliptical and the nozzle throat must be the quadrant of an ellipse. The thickness of the nozzle wall and flange must be such that distortion of the nozzle throat from strains caused by the pipeline temperature and pressure, flange bolting, or other methods of installing the nozzle in the pipeline must not cause the accuracy to degrade beyond the specified

limit. The outside diameter of the nozzle flange or the design of the flange facing must be such that the nozzle throat must be centered accurately in the pipe.

2.6.7.4 Venturi Tube

Venturi tube must be made of cast iron or cast steel and must have an accuracy of plus or minus 1 percent of full flow. The throat section must be lined with austenitic stainless steel. Thermal expansion characteristics of the lining must be the same as that of the throat casting material. The surface of the throat lining must be machined to a plus or minus 50 micro inch finish, including the short curvature leading from the converging entrance section into the throat.

2.6.7.5 Annular Pitot Tube

Annular pitot tube must be made of austenitic stainless steel with an accuracy of plus or minus 2 percent of full flow and a repeatability of plus or minus 0.5 percent of measured value. The unit must have at least one static port and no less than four total head pressure ports with an averaging manifold.

2.6.7.6 Insertion Turbine Flowmeter

Provide dual axial turbine flowmeter with all installation hardware necessary to enable insertion and removal of the meter without system shutdown. All parts must meet or exceed the pressure classification of the pipe system it is installed in. Insertion Turbine Flowmeter accuracy must be plus or minus 0.5 percent of rate at calibrated velocity., within plus or minus of rate over a 10:1 turndown and within plus or minus 2 percent of rate over a 50:1 turndown. Repeatability must be plus or minus 0.25 percent of reading. The meter flow sensing element must operate over a range suitable for the installed location with a pressure loss limited to 1 percent of operating pressure at maximum flow rate. The flowmeter ,must include either dry contact pulse outputs, 4-20mA, 0-10Vdc or 0-5Vdc outputs. The turbine rotor assembly must be constructed of Series 300 stainless steel and use Teflon seals.

2.6.7.7 Vortex Shedding Flowmeter

Vortex Shedding Flowmeter accuracy must be within plus or minus 0.8 percent of the actual reading over the range of the meter. Steam meters must contain density compensation by direct measurement of temperature. Mass flow inferred from specified steam pressure are not acceptable. The flow meter body must be made of austenitic stainless steel and include a weather tight NEMA 4X electronics enclosure. The vortex shedding flowmeter body must not require removal from the piping in order to replace the shedding sensor.

2.6.7.8 Ultrasonic Flow Meter

Provide Ultrasonic Flow Meters complete with matched transducers, self aligning installation hardware and transducer cables. Ultrasonic transducers must be optimized for the specific pipe and process conditions for the application. The flow meter accuracy must plus or minus 1 percent of rate from 0 to 40 ft/sec. The flowmeter must include either dry contact pulse outputs, 4-20mA, 0-10Vdc or 0-5Vdc output.

2.6.7.9 Insertion Magnetic Flow Meter

Provide insertion type magnetic flowmeters with all installation hardware necessary to enable insertion and removal of the meter without system shutdown. All parts must meet or exceed the pressure classification of the pipe system it is installed in. Flowmeter accuracy must be no greater than plus or minus 1 percent of rate from 2 to 20 feet/sec. Wetted material parts must be 300 series stainless steel. The flowmeter must include either dry contact pulse outputs, 4-20mA, 0-10Vdc or 0-5Vdc outputs.

2.6.7.10 Positive Displacement Flow Meter

The flow meter must be a direct reading, gerotor, nutating disc or vane type displacement device rated for liquid service as indicated. A counter must be mounted on top of the meter, and must consist of a non-resettable mechanical totalizer for local reading, and a pulse transmitter for remote reading. The totalizer must have a six digit register to indicate the volume passed through the meter in gallons, and a sweep-hand dial to indicate down to 0.25 gallons. The pulse transmitter must have a hermetically sealed reed switch which is activated by magnets fixed on gears of the counter. The meter must have a bronze body with threaded or flanged connections as required for the application. Output accuracy must be plus or minus 2 percent of the flow range. The maximum pressure drop at full flow must be 5 psig.

2.6.7.11 Flow Meters, Paddle Type

Sensor must be non-magnetic, with forward curved impeller blades designed for water containing debris. Sensor accuracy must be plus or minus 1 percent of rate of flow, minimum operating flow velocity must be 1 foot per second. Sensor repeatability and linearity must be plus or minus 1 percent. Materials which will be wetted must be made from non-corrosive materials and must not contaminate water. The sensor must be rated for installation in pipes of 3 to 40 inch diameters. The transmitter housing must be a NEMA 250 Type 4 enclosure.

2.6.7.12 Flow Switch

Flow switch must have a repetitive accuracy of plus or minus 10 percent of actual flow setting. Switch actuation must be adjustable over the operating flow range, and must be sized for the application such that the setpoint is between 25 percent and 75 percent of the full range.. The switch must have Form C snap-action contacts, rated for the application. The flow switch must have non flexible paddle with magnetically actuated contacts and be rated for service at a pressure greater than the installed conditions. Flow switch for use in sewage system must be rated for use in corrosive environments encountered.

2.6.7.13 Gas Flow Meter

Gas flow meter must be diaphragm or bellows type (gas positive displacement meters) for flows up to 2500 SCFH and axial flow turbine type for flows above 2500 SCFH, designed specifically for natural gas supply metering, and rated for the pressure, temperature, and flow rates of the installation. Meter must have a minimum turndown ratio of 10 to 1 with an accuracy of plus or minus 1 percent of actual flow rate. The meter index must include a direct reading mechanical totalizing register and electrical impulse dry contact output for remote monitoring. The

electrical impulse dry contact output must not require field adjustment or calibration. The electrical impulse dry contact output must have a minimum resolution of 100 cubic feet of gas per pulse and must not exceed 15 pulses per second at the design flow.

2.6.8 Electrical Instruments

Provide Electrical Instruments with an input range as indicated or sized for the application. Unless otherwise specified, AC instrumentation must be suitable for 60 Hz operation.

2.6.8.1 Current Transducers

Current transducers must accept an AC current input and must have an accuracy of plus or minus 2 percent of full scale. The device must have a means for calibration. Current transducers for variable frequency applications must be rated for variable frequency operation.

2.6.8.2 Current Sensing Relays (CSRs)

Current sensing relays (CSRs) must provide a normally-open contact with a voltage and amperage rating greater than its connected load. Current sensing relays must be of split-core design. The CSR must be rated for operation at 200 percent of the connected load. Voltage isolation must be a minimum of 600 volts. The CSR must auto-calibrate to the connected load or be adjustable and field calibrated. Current sensors for variable frequency applications must be rated for variable frequency operation.

2.6.8.3 Voltage Transducers

Voltage transducers must accept an AC voltage input and have an accuracy of plus or minus 0.25 percent of full scale. The device must have a means for calibration. Line side fuses for transducer protection must be provided.

2.6.8.4 Energy Metering

2.6.8.4.1 Watt or Watthour Transducers

Watt transducers must measure voltage and current and must output kW or kWh or both kW and kWh as indicated. kW outputs must have an accuracy of plus or minus 0.5 percent over a power factor range of 0.1 to 1. kWh outputs must have an accuracy of plus or minus 0.5 percent over a power factor range of 0.1 to 1.

2.6.8.4.2 Watthour Revenue Meter (with and without Demand Register)

All Watthour revenue meters must measure voltage and current and must be in accordance with ANSI C12.1 with an ANSI C12.20 Accuracy class of 0.5 and must have pulse initiators for remote monitoring of Watthour consumption. Pulse initiators must consist of form C contacts with a current rating not to exceed two amperes and voltage not to exceed 500 V, with combinations of VA not to exceed 100 VA, and a life rating of one billion operations. Meter sockets must be in accordance with NEMA/ANSI C12.10. Watthour revenue meters with demand registers must output instantaneous demand in addition to the pulse initiators.

2.6.8.4.3 Steam Meters

Steam meters must be the vortex type, with pressure compensation, a minimum turndown ratio of 10 to 1, and an output signal compatible with the DDC system.

2.6.8.4.4 Hydronic BTU Meters

The BTU meter is to be supplied with wall mount hardware and be capable of being installed remote from the flow meter. The BTU meter must include an LCD display for local indication of energy rate and for display of parameters and settings during configuration. Each BTU meter must be factory configured for its specific application and be completely field configurable by the user via a front panel keypad (no special interface device or computer required). The unit must output Energy Rate, Energy Total, Flow Rate, Supply Temperature, and Return Temperature. An integral transmitter is to provide a linear analog or configurable pulse output signal representing the energy rate; and the signal must be compatible with building automation system DDC Hardware to which the output is connected.

2.6.9 pH Sensor

The sensor must be suitable for applications and chemicals encountered in water treatment systems of boilers, chillers and condenser water systems. Construction, wiring, fittings and accessories must be corrosion and chemical resistant with fittings for tank or suspension installation. Housing must be polyvinylidene fluoride with O-rings made of chemical resistant materials which do not corrode or deteriorate with extended exposure to chemicals. The sensor must be encapsulated. Periodic replacement must not be required for continued sensor operation. Sensors must use a ceramic junction and pH sensitive glass membrane capable of withstanding a pressure of 100 psig at 150 degrees F. The reference cell must be double junction configuration. Sensor range must be 0 to 12 pH, stability 0.05, sensitivity 0.02, and repeatability of plus or minus 0.05 pH value, response of 90 percent of full scale in one second and a linearity of 99 percent of theoretical electrode output measured at 76 degrees F.

2.6.10 Oxygen Analyzer

Oxygen analyzer must consist of a zirconium oxide sensor for continuous sampling and an air-powered aspirator to draw flue gas samples. The analyzer must be equipped with filters to remove flue air particles. Sensor probe temperature rating must be 815 degrees F. The sensor assembly must be equipped for flue flange mounting.

2.6.11 Carbon Monoxide Analyzer

Carbon monoxide analyzer must consist of an infrared light source in a weather proof steel enclosure for duct or stack mounting. An optical detector/analyzer in a similar enclosure, suitable for duct or stack mounting must be provided. Both assemblies must include internal blower systems to keep optical windows free of dust and ash at all times. The third component of the analyzer must be the electronics cabinet. Automatic flue gas temperature compensation and manual/automatic zeroing devices must be provided. Unit must read parts per million (ppm) of carbon monoxide in the range of to ppm and the response time must be less than 3 seconds to 90 percent value. Unit measurement range must not

exceed specified range by more than 50 percent. Repeatability must be plus or minus 1 percent of full scale with an accuracy of plus or minus 1 percent of full scale.

2.6.12 Occupancy Sensors

Occupancy sensors must have occupancy-sensing sensitivity adjustment and an adjustable off-delay timer with a setpoint of 15 minutes. Adjustments accessible from the face of the unit are preferred. Occupancy sensors must be rated for operation in ambient air temperatures ranging from 40 to 95 degrees F or temperatures normally encountered in the installed location. Sensors integral to wall mount on-off light switches must have an auto-off switch. Wall switch sensors must be decorator style and must fit behind a standard decorator type wall plate. All occupancy sensors, power packs, and slave packs must be UL listed. In addition to any outputs required for lighting control, the occupancy sensor must provide an output for the HVAC control system.

2.6.12.1 Passive Infrared (PIR) Occupancy Sensors

PIR occupancy sensors must have a multi-level, multi-segmented viewing lens and a conical field of view with a viewing angle of 180 degrees and a detection of at least 20 feet unless otherwise indicated or specified. PIR Sensors must provide field-adjustable background light-level adjustment with an adjustment range suitable to the light level in the sensed area, room or space. PIR sensors must be immune to false triggering from RFI and EMI.

2.6.12.2 Ultrasonic Occupancy Sensors

Ultrasonic sensors must operate at a minimum frequency 32 kHz and must be designed to not interfere with hearing aids.

2.6.12.3 Dual-Technology Occupancy Sensor (PIR and Ultrasonic)

Dual-Technology Occupancy Sensors must meet the requirements of both PIR and Ultrasonic Occupancy Sensors.

2.6.13 Vibration Switch

Vibration switch must be solid state, enclosed in a NEMA 250 Type 4 or Type 4X housing with sealed wire entry. Unit must have two independent sets of Form C switch contacts with one set to shutdown equipment upon excessive vibration and a second set for monitoring alarm level vibration. The vibration sensing range must be a true rms reading, suitable for the application. The unit must include either displacement response for low speed or velocity response for high speed application. The frequency range must be at least 3 Hz to 500 Hz. Contact time delay must be 3 seconds. The unit must have independent start-up and running delay on each switch contact. Alarm limits must be adjustable and setpoint accuracy must be plus or minus 10 percent of setting with repeatability of plus or minus 2 percent.

2.6.14 Conductivity Sensor

Sensor must include local indicating meter and must be suitable for measurement of conductivity of water in boilers, chilled water systems, condenser water systems, distillation systems, or potable water systems as indicated. Sensor must sense from 0 to 10 microSeimens per centimeter

($\mu\text{S}/\text{cm}$) for distillation systems, 0 to 100 $\mu\text{S}/\text{cm}$ for boiler, chilled water, and potable water systems and 0 to 1000 $\mu\text{S}/\text{cm}$ for condenser water systems. Contractor must field verify the ranges for particular applications and adjust the range as required. The output must be temperature compensated over a range of 32 to 212 degrees F. The accuracy must be plus or minus 2 percent of the full scale reading. Sensor must have automatic zeroing and must require no periodic maintenance or recalibration.

2.6.15 Compressed Air Dew Point Sensor

Sensor must be suitable for measurement of dew point from -40 +80 degrees F over a pressure range of 0 to 150 psig. The transmitter must provide both dry bulb and dew point temperatures on separate outputs. The end to end accuracy of the dew point must be plus or minus 5 degrees F and the dry bulb must be plus or minus 1 degree F. Sensor must be automatic zeroing and must require no normal maintenance or periodic recalibration.

2.6.16 NOx Monitor

Monitor must continuously monitor and give local indication of boiler stack gas for NOx content. It must be a complete system designed to verify compliance with the Clean Air Act standards for NOx normalized to a 3 percent oxygen basis and must have a range of from 0 to 100 ppm. Sensor must be accurate to plus or minus 5 ppm. Sensor must output NOx and oxygen levels and binary output that changes state when the NOx level is above a locally adjustable NOx setpoint. Sensor must have normal, trouble and alarm lights. Sensor must have heat traced lines if the stack pickup is remote from the sensor. Sensor must be complete with automatic zero and span calibration using a timed calibration gas system, and must not require periodic maintenance or recalibration.

2.6.17 Turbidity Sensor

Sensor must include a local indicating meter and must be suitable for measurement of turbidity of water. Sensor must sense from 0 to 1000 Nephelometric Turbidity Units (NTU). Range must be field-verified for the particular application and adjusted as required. The output must be temperature compensated over a range of 32 to 212 degrees F. The accuracy must be plus or minus 5 percent of full scale reading. Sensor must have automatic zeroing and must not require periodic maintenance or recalibration.

2.6.18 Chlorine Detector

The detector must measure concentrations of chlorine in water in the range 0 to 20 ppm with a repeatability of plus or minus 1 percent of full scale and an accuracy of plus or minus 2 percent of full scale. The Chlorine Detector transmitter must be housed in a non-corrosive NEMA 250 Type 4X enclosure. Detector must include a local panel with adjustable alarm trip level, local audio and visual alarm with silence function.

2.6.19 Floor Mounted Leak Detector

Leak detectors must use electrodes mounted at slab level with a minimum built-in-vertical adjustment of 0.125 inches. Detector must have a binary output. The indicator must be manual reset type.

2.6.20 Temperature Switch

2.6.20.1 Duct Mount Temperature Low Limit Safety Switch (Freezestat)

Duct mount temperature low limit switches (Freezestats) must be manual reset, low temperature safety switches at least 1 foot long per square foot of coverage which must respond to the coldest 18 inch segment with an accuracy of plus or minus 3.6 degrees F. The switch must have a field-adjustable setpoint with a range of at least 30 to 50 degrees F. The switch must have two sets of contacts, and each contact must have a rating greater than its connected load. Contacts must open or close upon drop of temperature below setpoint as indicated and must remain in this state until reset.

2.6.20.2 Pipe Mount Temperature Limit Switch (Aquastat)

Pipe mount temperature limit switches (aquastats) must have a field adjustable setpoint between 60 and 90 degrees F, an accuracy of plus or minus 3.6 degrees F and a 10 degrees F fixed deadband. The switch must have two sets of contacts, and each contact must have a rating greater than its connected load. Contacts must open or close upon change of temperature above or below setpoint as indicated.

2.6.21 Damper End Switches

Each end switch must be a hermetically sealed switch with a trip lever and over-travel mechanism. The switch enclosure must be suitable for mounting on the duct exterior and must permit setting the position of the trip lever that actuates the switch. The trip lever must be aligned with the damper blade.

End switches integral to an electric damper actuator are allowed as long as at least one is adjustable over the travel of the actuator.

2.6.22 Air Quality Sensors

Provide full spectrum air quality sensors using a hot wire element based on the Taguchi principle. The sensor must monitor a wide range of gaseous volatile organic components common in indoor air contaminants like paint fumes, solvents, cigarette smoke, and vehicle exhaust. The sensor must automatically compensate for temperature and humidity, have span and calibration potentiometers, operate on 24 VDC power with output of 0-10 VDC, and have a service rating of 32 to 140 degrees F and 5 to 95 percent relative humidity.

2.7 OUTPUT DEVICES

2.7.1 Actuators

Actuators must be electric (electronic) . All actuators must be normally open (NO), normally closed (NC) or fail-in-last-position (FILP) as indicated. Normally open and normally closed actuators must be of mechanical spring return type. Electric actuators must have an electronic cut off or other means to provide burnout protection if stalled. Actuators must have a visible position indicator. Electric actuators must provide position feedback to the controller as indicated. Actuators must smoothly and fully open or close the devices to which they are applied. Electric actuators must have a full stroke response time in both directions of 90 seconds or less at rated load. Electric actuators must

be of the foot-mounted type with an oil-immersed gear train or the direct-coupled type. Where multiple electric actuators operate from a common signal, the actuators must provide an output signal identical to its input signal to the additional devices. All actuators must be rated for their operating environment. Actuators used outdoors must be designed and rated for outdoor use. Actuators under continuous exposure to water, such as those used in sumps, must be submersible.

Actuators incorporating an integral network connection are considered DDC Hardware and must meet the DDC Hardware requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

2.7.1.1 Valve Actuators

Valve actuators must provide shutoff pressures and torques as indicated on the Valve Schedule.

2.7.1.2 Damper Actuators

Damper actuators must provide the torque necessary per damper manufacturer's instructions to modulate the dampers smoothly over its full range of operation and torque must be at least 6 inch-pounds/1 square foot of damper area for opposed blade dampers and 9 inch-pounds/1 square foot of damper area for parallel blade dampers.

2.7.1.3 Electric Actuators

Each actuator must have distinct markings indicating the full-open and full-closed position. Each actuator must deliver the torque required for continuous uniform motion and must have internal end switches to limit the travel, or be capable of withstanding continuous stalling without damage. Actuators must function properly within 85 to 110 percent of rated line voltage. Provide actuators with hardened steel running shafts and gears of steel or copper alloy. Fiber or reinforced nylon gears may be used for torques less than 16 inch-pounds..

- a. Two-position actuators must be single direction, spring return, or reversing type. Two position actuator signals may either be the control power voltage or line voltage as needed for torque or appropriate interlock circuits.
- b. Modulating actuators must be capable of stopping at any point in the cycle, and starting in either direction from any point. Actuators must be equipped with a switch for reversing direction, and a button to disengage the clutch to allow manual adjustments. Provide the actuator with a hand crank for manual adjustments, as applicable. Modulating actuator input signals can either be a 4 to 20 mAdc or a 0-10 VDC signal.
- c. Floating or pulse width modulation actuators are acceptable for non-fail safe applications unless indicated otherwise provided that the floating point control (timed actuation) must have a scheduled re-calibration of span and position no more than once a day and no less than once a week. The schedule for the re-calibration should not affect occupied conditions and be staggered between equipment to prevent falsely loading or unloading central plant equipment.

2.7.2 Solenoid-Operated Electric to Pneumatic Switch (EPS)

Solenoid-Operated Electric to Pneumatic Switches (EPS) must accept a voltage input to actuate its air valve. Each valve must have three-port operation: common, normally open, and normally closed. Each valve must have an outer cast aluminum body and internal parts of brass, bronze, or stainless steel. The air connection must be a 0.38 inch NPT threaded connection. Valves must be rated for 50 psig.

2.7.3 Electric to Pneumatic Transducers (EP)

Electric to Pneumatic Transducers (EPs) must convert either a 4-20 mA dc input signal, a 0-10 V dc input signal to a proportional 0 to 20 psig pneumatic output. The EP must withstand pressures at least 150 percent of the system supply air pressure (main air). EPs must include independent offset and span adjustment. Steady state air consumption must not be greater than 0.05 scfm. EPs must have a manual adjustable override for the EP pneumatic output. EPs must have sufficient output capacity to provide full range stroke of the actuated device in both directions within 90 seconds.

2.7.4 Relays

Relays must have contacts rated for the intended application, indicator light, and dust proof enclosure. The indicator light must be lit when the coil is energized and off when coil is not energized.

Control relay contacts must have utilization category and ratings selected for the application. Each set of contacts must incorporate a normally open (NO), normally closed (NC) and common contact. Relays must be rated for a minimum life of one million operations.

2.8 USER INPUT DEVICES

User Input Devices, including potentiometers, switches and momentary contact push-buttons. Potentiometers must be of the thumb wheel or sliding bar type. Momentary Contact Push-Buttons may include an adjustable timer for their output. User input devices must be labeled for their function.

2.9 MULTIFUNCTION DEVICES

Multifunction devices are products which combine the functions of multiple sensor, user input or output devices into a single product. Unless otherwise specified, the multifunction device must meet all requirements of each component device. Where the requirements for the component devices conflict, the multifunction device must meet the most stringent of the requirements.

2.9.1 Current Sensing Relay Command Switch

The Current Sensing Relay portion must meet all requirements of the Current Sensing Relay input device. The Command Switch portion must meet all requirements of the Relay output device except that it must have at least one normally-open (NO) contact.

Current Sensing Relays used for Variable Frequency Drives must be rated for Variable Frequency applications unless installed on the source side of the drive. If used in this situation, the threshold for showing status

must be set to allow for the VFD's control power when the drive is not enabled and provide indication of operation when the drive is enabled at minimum speed.

2.9.2 Space Sensor Module

Space Sensor Modules must be multifunction devices incorporating a temperature sensor and one or more of the following as specified and indicated on the Space Sensor Module Schedule:

- a. A temperature indicating device.
- b. A User Input Device which must adjust a temperature setpoint output.
- c. A User Input Momentary Contact Button and an output to the control system indicating zone occupancy.
- d. A three position User Input Switch labeled to indicate heating, cooling and off positions ('HEAT-COOL-OFF' switch) and providing corresponding outputs to the control system.
- e. A two position User Input Switch labeled with 'AUTO' and 'ON' positions and providing corresponding output to the control system..
- f. A multi-position User Input Switch with 'OFF' and at least two fan speed positions and providing corresponding outputs to the control system.

Space Sensor Modules cannot contain mercury (Hg).

PART 3 EXECUTION

3.1 INSTALLATION

3.1.1 General Installation Requirements

Perform the installation under the supervision of competent technicians regularly employed in the installation of DDC systems.

3.1.1.1 Device Mounting Criteria

All devices must be installed in accordance with manufacturer's recommendations and as specified and indicated. Control devices to be installed in piping and ductwork must be provided with required gaskets, flanges, thermal compounds, insulation, piping, fittings, and manual valves for shutoff, equalization, purging, and calibration. Strap-on temperature sensing elements must not be used except as specified. Spare thermowells must be installed adjacent to each thermowell containing a sensor and as indicated. Devices located outdoors must have a weathershield.

3.1.1.2 Labels and Tags

Match labels and tags to the unique identifiers indicated on the As-Built drawings. Label all enclosures and instrumentation. Tag all sensors and actuators in mechanical rooms. Tag airflow measurement arrays to show flow rate range for signal output range, duct size, and pitot tube AFMA flow coefficient. Tag duct static pressure taps at the location of the pressure tap. Provide plastic or metal tags, mechanically attached

directly to each device or attached by a metal chain or wire. Labels exterior to protective enclosures must be engraved plastic and mechanically attached to the enclosure or instrumentation. Labels inside protective enclosures may be attached using adhesive, but must not be hand written.

3.1.2 Weathershield

Provide weathershields for sensors located outdoors. Install weathershields such that they prevent the sun from directly striking the sensor and prevent rain from directly striking or dripping onto the sensor. Install weather shields with adequate ventilation so that the sensing element responds to the ambient conditions of the surroundings. When installing weathershields near outside air intake ducts, install them such that normal outside air flow does not cause rainwater to strike the sensor.

3.1.3 Room Instrument Mounting

Mount room instruments, including but not limited to wall mounted non-adjustable space sensor modules and sensors located in occupied spaces, 48 inches above the floor unless otherwise indicated. Install adjustable devices to be ADA compliant unless otherwise indicated on the Room Sensor Schedule:

- a. Space Sensor Modules for Fan Coil Units may be either unit or wall mounted but not mounted on an exterior wall.
- b. Wall mount all other Space Sensor Modules.

3.1.4 Indication Devices Installed in Piping and Liquid Systems

Provide snubbers for gauges in piping systems subject to pulsation. For gauges for steam service use pigtail fittings with cock. Install thermometers and temperature sensing elements in liquid systems in thermowells. Provide spare Pressure/Temperature Ports (Pete's Plug) for all temperature and pressure sensing elements installed in liquid systems for calibration/testing.

3.1.5 Occupancy Sensors

Provide a sufficient quantity of occupancy sensors to provide complete coverage of the area (room or space). Occupancy sensors are to be ceiling mounted. Install occupancy sensors in accordance with NFPA 70 requirements and the manufacturer's instructions. Do not locate occupancy sensors within 6 feet of HVAC outlets or heating ducts, or where they can "see" beyond any doorway. Installation above doorway(s) is preferred. Do not use ultrasonic sensors in spaces containing ceiling fans. Install sensors to detect motion to within 2 feet of all room entrances and to not trigger due to motion outside the room. Set the off-delay timer to 15 minutes unless otherwise indicated. Adjust sensors prior to beneficial occupancy, but after installation of furniture systems, shelving, partitions, etc. For each controlled area, provide one hundred percent coverage capable of detecting small hand-motion movements, accommodating all occupancy habits of single or multiple occupants at any location within the controlled room.

3.1.6 Switches

3.1.6.1 Temperature Limit Switch

Provide a temperature limit switch (freezestat) to sense the temperature at the location indicated. Provide a sufficient number of temperature limit switches (freezestats) to provide complete coverage of the duct section but no less than 1 foot in length per square foot of cross sectional area. Install manual reset limit switches in approved, accessible locations where they can be reset easily. Install temperature limit switch (freezestat) sensing elements in a side-to-side (not top-to-bottom) serpentine pattern with the relay section at the highest point and in accordance with the manufacturer's installation instructions.

3.1.6.2 Hand-Off Auto Switches

Wire safety controls such as smoke detectors and freeze protection thermostats to protect the equipment during both hand and auto operation.

3.1.7 Temperature Sensors

Install temperature sensors in locations that are accessible and provide a good representation of sensed media. Installations in dead spaces are not acceptable. Calibrate and install sensors according to manufacturer's instructions. Select sensors only for intended application as designated or recommended by manufacturer.

3.1.7.1 Room Temperature Sensors

Mount the sensors on interior walls to sense the average room temperature at the locations indicated. Avoid locations near heat sources such as copy machines or locations by supply air outlet drafts. Mount the center of all user-adjustable sensors 48 inches above the floor to meet ADA requirements. Non user-adjustable sensors can be mounted as indicated in paragraph ROOM INSTRUMENT MOUNTING.

3.1.7.2 Duct Temperature Sensors

3.1.7.2.1 Probe Type

Place tip of the sensor in the middle of the airstream or in accordance with manufacturer's recommendations or instructions. Provide a gasket between the sensor housing and the duct wall. Seal the duct penetration air tight. When installed in insulated duct, provide enclosure or stand off fitting to accommodate the thickness of duct insulation to allow for maintenance or replacement of the sensor and wiring terminations. Seal the duct insulation penetration vapor tight.

3.1.7.2.2 Averaging Type

Weave the sensing element in a serpentine fashion from side to side perpendicular to the flow, across the duct or air handler cross-section, using durable non-metal supports in accordance with manufacturer's installation instructions. Avoid tight radius bends or kinking of the sensing element. Prevent contact between the sensing element and the duct or air handler internals. Provide a duct access door at the sensor location. The access door must be hinged on the side, factory insulated, have cam type locks, and be as large as the duct will permit, maximum 18 by 18 inches. For sensors inside air handlers, the sensors must be fully

accessible through the air handler's access doors without removing any of the air handler's internals.

3.1.7.3 Immersion Temperature Sensors

Provide thermowells for sensors measuring piping, tank, or pressure vessel temperatures. Locate wells to sense continuous flow conditions. Do not install wells using extension couplings. When installed on insulated piping, provide stand enclosure or stand off fitting to accommodate the thickness of the pipe insulation and allow for maintenance or replacement of the sensor or wiring terminations. Where piping diameters are smaller than the length of the wells, provide wells in piping at elbows to sense flow across entire area of well. Wells must not restrict flow area to less than 70 percent of pipe area. Increase piping size as required to avoid restriction. Provide the sensor well with a heat-sensitive transfer agent between the sensor and the well interior ensuring contact between the sensor and the well.

3.1.7.4 Outside Air Temperature Sensors

Provide outside air temperature sensors on the building's north side with a protective weather shade that does not inhibit free air flow across the sensing element, and protects the sensor from snow, ice, and rain. Location must not be near exhaust hoods and other areas such that it is not influenced by radiation or convection sources which may affect the reading. Provide a shield to shade the sensor from direct sunlight.

3.1.8 Air Flow Measurement Arrays (AFMA)

Locate Outside Air AFMAs downstream from the Outside Air filters.

Install AFMAs with the manufacturer's recommended minimum distances between upstream and downstream disturbances. Airflow straighteners may be used to reduce minimum distances as recommended by the AFMA manufacturer.

3.1.9 Duct Static Pressure Sensors

Locate the duct static pressure sensing tap at 75 percent of the distance between the first and last air terminal units. If the transmitter output is a 0-10Vdc signal, locate the transmitter in the same enclosure as the air handling unit (AHU) controller for the AHU serving the terminal units. If a remote duct static pressure sensor is to be used, run the signal wire back to the controller for the air handling unit.

3.1.10 Relative Humidity Sensors

Install relative humidity sensors in supply air ducts at least 10 feet downstream of humidity injection elements.

3.1.11 Meters

3.1.11.1 Flowmeters

Install flowmeters to ensure minimum straight unobstructed piping for at least 10 pipe diameters upstream and at least 5 pipe diameters downstream of the flowmeter, and in accordance with the manufacturer's installation instructions.

3.1.11.2 Energy Meters

Locate energy meters as indicated. Connect each meter output to the DDC system, to measure both instantaneous demand/energy and other variables as indicated.

3.1.12 Dampers

3.1.12.1 Damper Actuators

Provide spring return actuators which fail to a position that protects the served equipment and space on all control dampers related to freeze protection or force protection. For all outside, makeup and relief dampers provide dampers which fail closed. Terminal fan coil units, terminal VAV units, convectors, and unit heaters may be non-spring return unless indicated otherwise. Do not mount actuators in the air stream. Do not connect multiple actuators to a common drive shaft. Install actuators so that their action seal the damper to the extent required to maintain leakage at or below the specified rate and so that they move the blades smoothly throughout the full range of motion.

3.1.12.2 Damper Installation

Install dampers straight and true, level in all planes, and square in all dimensions. Dampers must move freely without undue stress due to twisting, racking (parallelogramming), bowing, or other installation error. External linkages must operate smoothly over the entire range of motion, without deformation or slipping of any connecting rods, joints or brackets that will prevent a return to it's normal position. Blades must close completely and leakage must not exceed that specified at the rated static pressure. Provide structural support for multi-section dampers. Acceptable methods of structural support include but are not limited to U-channel, angle iron, corner angles and bolts, bent galvanized steel stiffeners, sleeve attachments, braces, and building structure. Where multi-section dampers are installed in ducts or sleeves, they must not sag due to lack of support. Do not use jackshafts to link more than three damper sections. Do not use blade to blade linkages. Install outside and return air dampers such that their blades direct their respective air streams towards each other to provide for maximum mixing of air streams.

3.1.13 Valves

Install the valves in accordance with the manufacturer's instructions.

3.1.13.1 Valve Actuators

Provide spring return actuators on all control valves where freeze protection is required. Spring return actuators for terminal fan coil units, terminal VAV units, convectors, and unit heaters are not required unless indicated otherwise.

3.1.14 Thermometers and Gauges

3.1.14.1 Thermometers

Mount devices to allow reading while standing on the floor or ground, as applicable.

3.1.15 Wire and Cable

Provide complete electrical wiring for the Control System, including wiring to transformer primaries. Wire and Cable must be installed without splices between control devices and in accordance with NFPA 70 and NFPA 90A. Instrumentation grounding must be installed per the device manufacturer's instructions and as necessary to prevent ground loops, noise, and surges from adversely affecting operation of the system. Test installed ground rods as specified in IEEE 142. Cables and conductor wires must be tagged at both ends, with the identifier indicated on the shop drawings. Electrical work must be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and as indicated. Wiring external to enclosures must be run in raceways, except low-voltage control and low-voltage network wiring may be installed as follows:

- a. plenum rated cable in suspended ceilings over occupied spaces may be run without raceways
- b. nonmetallic-sheathed cables or metallic-armored cables may be installed as permitted by NFPA 70.

Install control circuit wiring not in raceways in a neat and safe manner. Wiring must not use the suspended ceiling system (including tiles, frames or hangers) for support. Where conduit or raceways are required, control circuit wiring must not run in the same conduit/raceway as power wiring over 50 volts. Run all circuits over 50 volts in conduit, metallic tubing, covered metal raceways, or armored cable.

3.1.16 Copper Tubing

Provide hard-drawn copper tubing in exposed areas and either hard-drawn or annealed copper tubing in concealed areas. Use only tool-made bends. Use only brass or copper solder joint type fittings, except for connections to apparatus. For connections to apparatus use brass compression type fittings.

3.1.17 Plastic Tubing

Install plastic tubing within covered raceways or conduit except when otherwise specified. Do not use plastic tubing for applications where the tubing could be subjected to a temperature exceeding 130 degrees F. For fittings, use brass or acetal resin of the compression or barbed push-on type for instrument service. Except in walls and exposed locations, plastic multitube instrument tubing bundle without conduit or raceway protection may be used where a number of air lines run to the same points, provided the multitube bundle is enclosed in a protective sheath, is run parallel to the building lines and is adequately supported as specified.

3.1.18 Compressed Air Stations

Mount the air compressor assembly on vibration eliminators, in accordance with ASME BPVC SEC VIII D1 for tank clearance. Connect the air line to the tank with a flexible pipe connector. Provide compressed air station specialties with required tubing, including condensate tubing to a floor drain. Compressed air stations must deliver control air meeting the requirements of ISA 7.0.01. Provide foundations and housekeeping pads for the HVAC control system air compressors in accordance with the air compressor manufacturer's instructions.

-- End of Section --

SECTION 23 09 23.02

BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS
02/19, CHG 1: 02/20

PART 1 GENERAL

1.1 SUMMARY

Provide a complete Direct Digital Control (DDC) system, except for the front end which is specified in Section 25 10 10 UTILITY MONITORING AND CONTROL (UMCS) FRONT END AND INTEGRATION, suitable for the control of the heating, ventilating and air conditioning (HVAC) and other building-level systems as specified and shown and in accordance with Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

1.1.1 System Requirements

Provide a system meeting the requirements of both Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and this Section and with the following characteristics:

- a. Except for Gateways, the control system must be an open implementation of BACnet technology using ASHRAE 135 as the communications protocol. The system must use standard ASHRAE 135 Objects and Properties. The system must use standard ASHRAE 135 Services exclusively for communication over the network. Gateways to packaged units must communicate with other DDC hardware using ASHRAE 135 exclusively and may communicate with packaged equipment using other protocols. The control system must be installed such that any two devices on the Internetwork can communicate using standard ASHRAE 135 Services.
- b. Install and configure control hardware to provide ASHRAE 135 Objects and Properties as indicated and as needed to meet the requirements of this specification.

1.1.2 Verification of Specification Requirements

Review all specifications related to the control system installation and advise the Contracting Officer of any discrepancies before performing any work. If Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC or any other Section referenced in this specification is not included in the project specifications advise the Contracting Officer and either obtain the missing Section or obtain Contracting Officer approval before performing any work.

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE 135 (2020; Interpretation 1-8 2021; Errata 1-2

2021; Addenda CD 2021; Addenda BV-CE 2022;
Interpretation 9-12 2022; Interpretation
13-24 2023; Addenda BV-CF 2023; Errata 3
2023) BACnet-A Data Communication Protocol
for Building Automation and Control
Networks

BACNET TESTING LABORATORIES (BTL)

BTL Guide (v.50; 2022) BACnet Testing Laboratory
Implementation Guidelines

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 802.3 (2022) Ethernet

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-485 (1998a; R 2012) Electrical Characteristics
of Generators and Receivers for Use in
Balanced Digital Multipoint Systems

U.S. FEDERAL COMMUNICATIONS COMMISSION (FCC)

FCC Part 15 Radio Frequency Devices (47 CFR 15)

UNDERWRITERS LABORATORIES (UL)

UL 916 (2015; Reprint Oct 2021) UL Standard for
Safety Energy Management Equipment

1.3 DEFINITIONS

For definitions related to this section, see Section 23 09 00
INSTRUMENTATION AND CONTROL FOR HVAC.

1.4 SUBMITTALS

Submittal requirements related to this Section are specified in Section
23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

PART 2 PRODUCTS

All products used to meet this specification must meet the indicated
requirements, but not all products specified here will be required by
every project. All products must meet the requirements both Section
23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and this Section.

2.1 NETWORK HARDWARE

2.1.1 BACnet Router

All BACnet Routers must be BACnet/IP Routers and must perform layer 3
routing of ASHRAE 135 packets over an IP network in accordance with
ASHRAE 135 Annex J and Clause 6. The router must provide the appropriate
connection to the IP network and connections to one or more ASHRAE 135
MS/TP networks. Devices used as BACnet Routers must meet the
requirements for DDC Hardware, and must support the NM-RC-B BIBB.

2.1.2 BACnet Gateways

In addition to the requirements for DDC Hardware, the BACnet Gateway must meet the following requirements:

- a. It must perform bi-directional protocol translation from one non-ASHRAE 135 protocol to ASHRAE 135. BACnet Gateways must incorporate a network connection to an ASHRAE 135 network (either BACnet over IP in accordance with Annex J or MS/TP) and a separate connection appropriate for the non-ASHRAE 135 protocol and media.
- b. It must retain its configuration after a power loss of an indefinite time, and must automatically return to their pre-power loss state once power is restored.
- c. It must allow bi-directional mapping of data between the non-ASHRAE 135 protocol and Standard Objects as defined in ASHRAE 135. It must support the DS-RP-B BIBB for Objects requiring read access and the DS-WP-B BIBB for Objects requiring write access.
- d. It must support the DS-COV-B BIBB.

Although Gateways must meet DDC Hardware requirements they are not DDC Hardware and must not be used when DDC Hardware is required.

2.1.3 Ethernet Switch

Ethernet Switches must be managed switches and must autoconfigure between 10,100 and 1000 megabits per second (MBPS).

2.2 CONTROL NETWORK WIRING

- a. BACnet MS/TP communications wiring must be in accordance with ASHRAE 135. The wiring must use shielded, three wire (twisted-pair with reference) cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors must be less than 30 pF per foot.
- b. Building Control Network Backbone IP Network must use Ethernet media. Ethernet cables must be CAT-5e at a minimum and meet all requirements of IEEE 802.3 .

2.3 DIRECT DIGITAL CONTROL (DDC) HARDWARE

2.3.1 General Requirements

All DDC Hardware must meet the following requirements:

- a. It must be locally powered and must incorporate a light to indicate the device is receiving power.
- b. It must conform to the BTL Guide
- c. It must be BACnet Testing Laboratory (BTL) Listed.
- d. The Manufacturer's Product Data submittal for each piece of DDC Hardware must include the Protocol Implementation Conformance Statement (PICS) for that hardware as specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

- e. It must communicate and be interoperable in accordance with ASHRAE 135 and have connections for BACnet IP or MS/TP control network wiring.
- f. Other than devices controlling terminal units or functioning solely as a BACnet Router, it must support DS-COV-B, DS-RPM-A and DS-RPM-B BIBBs.
- g. Devices supporting the DS-RP-A BIBB must also support the DS-COV-A BIBB.
- h. Application programs, configuration settings and communication information must be stored in a manner such that they persist through loss of power:
 - (1) Application programs must persist regardless of the length of time power is lost.
 - (2) Configured settings must persist for any loss of power less than 2,500 hours.
 - (3) Communication information, including but not limited to COV subscriptions, event reporting destinations, Notification Class Object settings, and internal communication settings, must persist for any loss of power less than 2,500 hours.
- i. Internal Clocks:
 - (1) Clocks in DDC Hardware incorporating a Clock must continue to function for 120 hours upon loss of power to the DDC Hardware.
 - (2) DDC Hardware incorporating a Clock must support the DM-TS-B or DM-UTC-B BIBB.
- j. It must have all functionality indicated and required to support the application (Sequence of Operation or portion thereof) in which it is used, including but not limited to providing Objects as specified and as indicated on the Points Schedule.
- k. In addition to these general requirements and the DDC Hardware Input-Output (I/O) Function requirements, all DDC Hardware must also meet any additional requirements for the application in which it is used (e.g. scheduling, alarming, trending, etc.).
- l. It must meet FCC Part 15 requirements and have UL 916 or equivalent safety listing.
- m. Device must support Commandable Objects to support Override requirements as detailed in PART 3 EXECUTION
- n. User interfaces which allow for modification of Properties or settings must be password-protected.
- o. Devices communicating BACnet MS/TP must meet the following requirements:
 - (1) Must have a configurable Max_Master Property.
 - (2) DDC Hardware other than hardware controlling a single terminal unit must have a configurable Max_Info_Frames Property.

- (3) Must respond to any valid request within 50 msec with either the appropriate response or with a response of "Reply Postponed".
- (4) Must use twisted pair with reference and shield (3-wire media) wiring, or twisted pair with shield (2-wire media) wiring and use half-wave rectification.
- p. Devices communicating BACnet/IP must use UDP Port 0xBAC0. Devices with configurable UDP Ports must default to 0xBAC0.
- q. All Device IDs, Network Numbers, and BACnet MAC addresses of devices must be fully configurable without limitation, except MS/TP MAC addresses may be limited by ASHRAE 135 requirements.
- r. DDC Hardware controlling a single terminal unit must have:
 - (1) Objects (including the Device Object) with an Object Name Property of at least 8 characters in length.
 - (2) A configurable Device Object Name.
 - (3) A configurable Device Object Description Property at least 16 characters in length.
- s. Except for Objects in DDC Hardware controlling a single terminal unit, all Objects (including Device Objects) must:
 - (1) Have a configurable Object Name Property of at least 12 characters in length.
 - (2) Have a configurable Object Description Property of at least 24 characters in length.
- t. For programmable DDC Hardware, provide and license to the project site all programming software required to program the Hardware in accordance with Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.
- u. For programmable DDC Hardware, provide copies of the installed application programs (all software that is not common to every controller of the same manufacturer and model) as source code compatible with the supplied programming software in accordance with Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC. The submitted application program must be the complete application necessary for controller to function as installed and be sufficient to allow replacement of the installed controller with another controller of the same type.

2.3.2 Hardware Input-Output (I/O) Functions

DDC Hardware incorporating hardware input-output (I/O) functions must meet the following requirements:

2.3.2.1 Analog Inputs

DC Hardware analog inputs (AIs) must be implemented using ASHRAE 135 Analog Input Objects and perform analog to digital (A-to-D) conversion with a minimum resolution of 8 bits plus sign or better as needed to meet the accuracy requirements specified in Section 23 09 00. Signal

conditioning including transient rejection must be provided for each analog input. Analog inputs must be capable of being individually calibrated for zero and span. Calibration via software scaling performed as part of point configuration is acceptable. The AI must incorporate common mode noise rejection of at least 50 dB from 0 to 100 Hz for differential inputs, and normal mode noise rejection of at least 20 dB at 60 Hz from a source impedance of 10,000 ohms.

2.3.2.2 Analog Outputs

DDC Hardware analog outputs (AOs) must be implemented using ASHRAE 135 Analog Output Objects and perform digital to analog (D-to-A) conversion with a minimum resolution of 8 bits plus sign, and output a signal with a range of 4-20 mAdc or 0-10 Vdc. Analog outputs must be capable of being individually calibrated for zero and span. Calibration via software scaling performed as part of point configuration is acceptable. DDC Hardware with Hand-Off-Auto (H-O-A) switches for analog outputs must provide for overriding the output to 0 percent and to 100 percent

2.3.2.3 Binary Inputs

DDC Hardware binary inputs (BIs) must be implemented using ASHRAE 135 Binary Input Objects and accept contact closures and must ignore transients of less than 5 milli-second duration. Protection against a transient 50VAC must be provided.

2.3.2.4 Binary Outputs

DDC Hardware binary outputs (BOs) must be implemented using ASHRAE 135 Binary Output Objects and provide relay contact closures or triac outputs for momentary and maintained operation of output devices. DDC Hardware with H-O-A switches for binary outputs must provide for overriding the output open or closed.

2.3.2.4.1 Relay Contact Closures

Closures must have a minimum duration of 0.1 second. Relays must provide at least 180V of isolation. Electromagnetic interference suppression must be provided on all output lines to limit transients to 50 Vac. Minimum contact rating must be 0.5 amperes at 24 Vac.

2.3.2.4.2 Triac Outputs

Triac outputs must provide at least 180 V of isolation. Minimum contact rating must be 0.5 amperes at 24 Vac.

2.3.2.5 Pulse Accumulator

DDC Hardware pulse accumulators must be implemented using either an ASHRAE 135 Accumulator Object or an ASHRAE 135 Analog Value Object where the Present_Value is the totalized pulse count. Pulse accumulators must accept contact closures, ignore transients less than 5 msec duration, protect against transients of 50 VAC, and accept rates of at least 20 pulses per second.

2.3.2.6 ASHRAE 135 Objects for Hardware Inputs and Outputs

The requirements for use of ASHRAE 135 objects for hardware input and outputs includes devices where the hardware sensor or actuator is integral

to the controller (e.g. a VAV box with integral damper actuator, a smart sensor, a VFD, etc.)

2.3.2.7 Integrated H-O-A Switches

Where integrated H-O-A switches are provided on hardware outputs, controller must provide means of monitoring position or status of H-O-A switch. This feedback may be provided via any valid BACnet method, including the use of proprietary Objects, Properties, or Services.

2.3.3 Local Display Panel (LDP)

The Local Display Panels (LDPs) must be DDC Hardware with a display and navigation buttons or a touch screen display, and must provide display and adjustment of ASHRAE 135 Properties as indicated on the Points Schedule and as specified. LDPs must be either BTL Listed as a B-OD, B-OWS, B-AWS, or be an integral part of another piece of DDC Hardware listed as a B-BC. For LDPs listed as B-OWS or B-AWS, the hardware must be BTL listed and the product must come factory installed with all applications necessary for the device to function as an LDP.

The adjustment of values using display and navigation buttons must be password protected.

2.3.4 Expansion Modules and Tethered Hardware

A single piece of DDC Hardware may consist of a base unit and also:

- a. An unlimited number of hardware expansion modules, where the individual hardware expansion modules are designed to directly connect, both mechanically and electrically, to the base unit hardware. The expansion modules must be commercially available as an optional add-on to the base unit.
- b. A single piece of hardware connected (tethered) to a base unit by a single cable where the cable carries a proprietary protocol between the base unit and tethered hardware. The tethered hardware must not contain control logic and be commercially available as an optional add-on to the base unit as a single package.

Note that this restriction on tethered hardware does not apply to sensors or actuators using standard binary or analog signals (not a communications protocol); sensors or actuators using standard binary or analog signals are not considered part of the DDC Hardware.

Hardware capable of being installed stand-alone, or without a separate base unit, is DDC Hardware and must not be used as expansion modules or tethered hardware.

2.3.5 Supervisory Control Requirements

2.3.5.1 Scheduling Hardware

DDC Hardware used for scheduling must meet the following requirements:

- a. It must be BTL Listed as a B-BC and support the SCHED-E-B BIBB.
- b. It is preferred, but not required, that devices support the DM-OCD-B

BIBB on all Calendar and Schedule Objects, such that a front end BTL listed as a B-AWS may create or delete Calendar and Schedule Objects. It is also preferred but not required that devices supporting the DM-OCD-B BIBB accept any valid value for properties of Calendar and Schedule Objects. Note that there are additional requirements in the EXECUTION Part of this Section for Devices which do not support the DM-OCD-B BIBB as specified.

- c. The Date_List property of all Calendar Objects must be writable.
- d. The Present_Value Property of Schedule must support the following values: 1, 2, 3, 4.

2.3.5.2 Alarm Generation Hardware

DDC Hardware used for alarm generation must meet the following requirements:

- a. Device must support the AE-N-I-B BIBB
- b. The Recipient_List Property must be Writable for all Notification Class Objects used for alarm generation.
- c. For all Objects implementing Intrinsic Alarming, the following Properties must be Writable:
 - (1) Time_Delay
 - (2) High_Limit
 - (3) Low_Limit
 - (4) Deadband
 - (5) Event_Enable
 - (6) If the issue date of this project specification is after 1 January 2016, Time_Delay_Normal must be writable.
- d. For Event Enrollment Objects used for alarm generation, the following Properties must be Writable:
 - (1) Event_Parameters
 - (2) Event_Enable
 - (3) If the issue date of this project specification is after 1 January 2016, Time_Delay_Normal must be writable.
- e. It is preferred, but not required, that devices support the DM-OCD-B BIBB on all Notification Class Objects and Event Enrollment Objects, such that a front end BTL listed as a B-AWS may create or delete Notification Class Objects and Event Enrollment Objects. It is also preferred, but not required that devices supporting the DM-OCD-B BIBB accept any valid value as an initial value for properties of Notification Class Objects and Event Enrollment Objects. Note that there are additional requirements in the EXECUTION Part of this Section for devices which do not support the DM-OCD-B BIBB as specified.
- f. Devices provided to meet the the requirements indicated under "Support for Future Alarm Generation" in the EXECUTION part of this specification must support the AE-N-E-B BIBB.

2.3.5.3 Trending Hardware

DDC Hardware used for collecting trend data must meet the following requirements:

- a. Device must support Trend Log or Trend Log Multiple Objects.
- b. Device must support the T-VMT-I-B BIBB.
- c. Devices provided to meet the EXECUTION requirement for support of Future Trending must support the T-VMT-E-B BIBB.
- d. The following properties of all Trend Log or Trend Log Multiple Objects must be present and Writable:
 - Start_Time
 - Stop_Time
 - Log_DeviceObjectProperty
 - Log Interval Log interval must support an interval of at least 60 minutes duration.
- e. Trend Log Objects must support using Intrinsic Reporting to send a BUFFER_FULL event.
- f. The device must have a Notification Class Object for the BUFFER_FULL event. The Recipient_List Property must be Writable.
- g. Devices must support values of at least 1,000 for Buffer_Size Properties.
- h. It is preferred, but not required, that devices support the DM-OCD-B BIBB on all Trend Log Objects, such that a front end BTL listed as a A-AWS may create or delete Trend Log Objects. It is also preferred, but not required that devices supporting the DM-OCD-B BIBB accept any valid value as an initial value for properties of Trend Log Objects. Note that there are additional EXECUTION requirements for devices which do not support the DM-OCD-B BIBB as specified.

PART 3 EXECUTION

3.1 CONTROL SYSTEM INSTALLATION3.1.1 Building Control Network (BCN)

Install the Building Control Network (BCN) as a single BACnet Internetwork consisting of a single IP network as the BCN Backbone and zero or more BACnet MS/TP networks. Note that in some cases there may only be a single device on the BCN Backbone.

Except as permitted for the non-BACnet side of Gateways, use exclusively ASHRAE 135 networks.

3.1.1.1 Building Control Network IP Backbone

Install IP Network Cabling in conduit. Install Ethernet Switches in lockable enclosures. Install the Building Control Network (BCN) IP Backbone such that it is available at the Facility Point of Connection (FPOC) location as indicated. When the FPOC location is a room number, provide sufficient additional media to ensure that the Building Control Network (BCN) IP Backbone can be extended to any location in the room.

Use UDP port 0xBAC0 for all BACnet traffic on the IP network.

3.1.1.2 BACnet MS/TP Networks

When using MS/TP, provide MS/TP networks in accordance with ASHRAE 135 and in accordance with the ASHRAE 135 figure "Mixed Devices on 3-Conductor Cable with Shield" (Figure 9-1.4 in the 2012 version of ASHRAE 135). Ground the shield at the BACnet Router and at no other point. Ground the reference wire at the BACnet Router through a 100 ohm resistor and do not ground it at any other point. In addition:

- a. Provide each segment in a doubly terminated bus topology in accordance with TIA-485.
- b. Provide each segment with 2 sets of network bias resistors in accordance with ASHRAE 135, with one set of resistors at each end of the MS/TP network.
- c. Use 3 wire (twisted pair and reference) with shield media for all MS/TP media installed inside. Use fiber optic isolation in accordance with ASHRAE 135 for all MS/TP media installed outside buildings, or between multiple buildings.
- d. For 18 AWG cable, use segments with a maximum length of 4000 ft. When using greater distances or different wire gauges comply with the electrical specifications of TIA-485.
- e. For each controller that does not use the reference wire provide transient suppression at the network connection of the controller if the controller itself does not incorporate transient suppression.
- f. Install no more than 32 devices on each MS/TP segment. Do not use MS/TP to MS/TP routers.
- g. Connect each MS/TP network to the BCN backbone via a BACnet Router.
- h. For BACnet Routers, configure the MS/TP MAC address to 0. Assign MAC Addresses to other devices consecutively beginning at 1, with no gaps.
- i. Configure the Max_Master Property of all devices to be 31.

3.1.1.3 Building Control Network (BCN) Installation

Provide a building control network meeting the following requirements:

- a. Install all DDC Hardware connected to the Building Control Network.
- b. Where multiple pieces of DDC Hardware are used to execute one sequence, install all DDC Hardware executing that sequence on a single MS/TP network dedicated to that sequence.
- c. Traffic between BACnet networks must be exclusively via BACnet routers.

3.1.2 DDC Hardware

Install all DDC Hardware that connects to an IP network in lockable enclosure. Install other DDC Hardware that is not in suspended ceilings in lockable enclosures. For all DDC hardware with a user interface, coordinate with site to determine proper passwords and configure passwords into device.

- a. Except for zone sensors (thermostats), install all Tethered Hardware within 6 feet of its base unit.
- b. Install and configure all BTL-Listed devices in a manner consistent with their BTL Listing such that the device as provided still meets all requirements necessary for its BTL Listing.
- c. Install and configure all BTL-Listed devices in a manner consistent with the BTL Device Implementation Guidelines such that the device as provided meets all those Guidelines.

3.1.2.1 Device Identifiers, Network Addresses, and IP addresses

- a. Do not use any Device Identifier or Network Number already used by another BACnet system at the project site. Coordinate Device IDs and Network Numbers with the installation. The installation POC is .
- b. Coordinate device IP addresses with installation. The installation POC is .

3.1.2.2 Object Name Property and Object Description Property

Configure the Object_Names and Object_Descriptions properties of all Objects (including Device Objects) as indicated on the Points Schedule (Point Name and Point Description) and as specified. At a minimum:

- a. Except for DDC Hardware controlling a single terminal unit, configure the Object_Name and Object_Description properties of all Objects (including Device Objects) as indicated on the Points Schedule and as specified.
- b. In DDC Hardware controlling a single terminal unit, configure the Device Object_Name and Device Object_Description as indicated on the Points Schedule and as specified.

When Points Schedule entries exceed the length limitations in the device, notify Engineer and provide recommended alternatives for approval.

3.1.2.3 Hand-Off-Auto (H-O-A) Switches

Provide Hand-Off-Auto (H-O-A) switches for all DDC Hardware analog outputs and binary outputs used for control of systems other than terminal units, as specified and as indicated on the Points Schedule. Provide H-O-A switches that are integral to the controller hardware, an external device co-located with (in the same enclosure as) the controller, integral to the controlled equipment, or an external device co-located with (in the same enclosure as) the controlled equipment.

- a. For H-O-A switches integral to DDC Hardware, meet the requirements specified in paragraph DIRECT DIGITAL CONTROL (DDC) HARDWARE.
- b. For external H-O-A switches used for binary outputs, provide for overriding the output open or closed.
- c. For eternal H-O-A switches used for analog outputs, provide for overriding to 0 percent or 100 percent.

3.1.2.4 Local Display Panels

Provide LDPs to display and override values of ASHRAE 135 Object Properties as indicated on the Points Schedule. Install LDPs displaying points for anything other than a terminal unit in the same room as the equipment. Install LDPs displaying points for only terminal units in a mechanical room central to the group of terminal units it serves. For LDPs using WriteProperty to commandable objects to implement an override, write values with priority 9.

3.1.2.5 MS/TP Slave Devices

Configure all MS/TP devices as Master devices. Do not configure any devices to act as slave devices.

3.1.2.6 Change of Value (COV) and Read Property

- a. To the greatest extent possible, configure all devices to support the SubscribeCOV service (the DS-COV-B BIBB). At a minimum, all devices supporting the DS-RP-B BIBB, other than devices controlling only a single terminal unit, must be configured to support the DS-COV-B BIBB.
- b. Whenever supported by the server side, configure client devices to use the DS-COV-A BIBB.

3.1.2.7 Engineering Units

Configure devices to use English (Inch-Pound) engineering units as follows:

- a. Temperature in degrees F
- b. Air or natural gas flows in cubic feet per minute (CFM)
- c. Water in gallons per minute (GPM)
- d. Steam flow in pounds per hour (pph)
- e. Differential Air pressures in inches of water column (IWC)
- f. Water, steam, and natural gas pressures in PSI
- g. Enthalpy in BTU/lb
- h. Heating and cooling energy in MBTU (1MBTU = 1,000,000 BTU))
- i. Cooling load in tons (1 ton = 12,000 BTU/hour)
- j. Heating load in MBTU/hour (1MBTU = 1,000,000 BTU)
- k. Electrical Power: kilowatts (kW)
- l. Electrical Energy: kilowatt-hours (kWh)

3.1.2.8 Occupancy Modes

Use the following correspondence between value and occupancy mode whenever an occupancy state or value is required:

- a. OCCUPIED mode: a value of one

- b. UNOCCUPIED mode: a value of two
- c. WARM-UP/COOL-DOWN (PRE-OCCUPANCY) mode: a value of three

Note that elsewhere in this Section the Schedule Object is required to also support a value of four, which is reserved for future use. Also note that the behavior of a system in each of these occupancy modes is indicated in the sequence of operation for the system.

3.1.2.9 Use of BACnet Objects

Use only standard non-proprietary ASHRAE 135 Objects and services to accomplish the project scope of work as follows:

- a. Use Analog Input or Analog Output Objects for all analog hardware I/O. Do not use Analog Value Object for analog hardware I/O) .
- b. Use Binary Input or Binary Output Objects for all binary hardware I/O. Do not use Binary Value Objects for binary hardware I/O.
- c. Use Analog Value Objects for analog setpoints.
- d. Use Accumulator Objects or Analog Value Objects for pulse inputs.
- e. For occupancy modes, use Multistate Value Objects and the correspondence between value and occupancy mode specified in paragraph OCCUPANCY MODES.
- f. Use Schedule Objects and Calendar Objects for all scheduling. Use Trend Log Objects or Trend Log Multiple Objects for all trending and Notification Class Objects for trend log upload. Use a combination of Event Enrollment Objects, Intrinsic Alarming, and Notification Class Objects for alarm generation.
- g. For all other points shown on the Points Schedule as requiring an ASHRAE 135 Object, use the Object type shown on the Points Schedule or, if no Object Type is shown, use a standard Object appropriate to the point.

3.1.2.10 Use of Standard BACnet Services

Except as noted in this paragraph, for all DDC Hardware use Standard BACnet Services as defined in this specification (which excludes some ASHRAE 135 services) exclusively for application control functionality and communication.

DDC Hardware that cannot meet this requirement may use non-standard services provided they can provide identical functionality using Standard BACnet Services when communicating with BACnet devices from a different vendor. When implementing non-standard services, document all non-standard services in the DDC Hardware Schedule as specified and as specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

3.1.2.11 Device Application Configuration

- a. For every property, setting or value shown on the Points Schedule or otherwise indicated as Configurable, provide a value that is retained through loss of power and can be changed via one or more of:

(1) BACnet services (including proprietary services)

(2) Hardware settings on the device

b. For every property, setting or value shown on the Points Schedule or otherwise indicated as Operator Configurable, provide a value that is retained through loss of power and can be changed via one or more of:

(1) A Writable Property of a standard BACnet Object

(2) A Property of a standard BACnet Object that is Writable when Out_Of_Service is TRUE and Out_Of_Service is Writable.

3.1.3 Scheduling, Alarming, Trending, and Overrides

3.1.3.1 Scheduling

Configure schedules in BACnet Scheduling Objects to schedule systems as indicated on the Points Schedule and as specified using the indicated correspondence between value and occupancy mode. If no devices supports both the SCHED-E-B and DM-OCD-B BIBBS for Schedule Objects, provide 5 blank Schedule Objects in DDC Hardware BTL listed as B-BCs and supporting the SCHED-E-B BIBB for later use by the site.

Provide a separate schedule for each AHU including it's associated Terminal Units and for each stand-alone Terminal Unit (those not dependent upon AHU service) or group of stand-alone Terminal Units acting according to a common schedule.

3.1.3.2 Configuration of Alarm Generation

a. Send alarm events as Alarms (not Events).

b. Use the ConfirmedNotification Service for alarm events.

c. For alarm generation, support two priority levels for alarms: critical and non-critical. Configure the Priority of Notification Class Objects to use Priority 112 for critical and 224 for non-critical alarms.

d. Number of Notification Class Objects for Alarm Generation:

(1) If the device implements non-critical alarms, or if any Object in the device supports Intrinsic Alarms, then provide a single Notification Class Object specifically for (shared by) all non-critical alarms.

(2) If the device implements critical alarms, provide a single Notification Class Object specifically for (shared by) all critical alarms.

(3) If the device implements both critical and non-critical alarms, provide both Notification Class Objects (one for critical, one for

non-critical).

- (4) If the device controls equipment other than a single terminal unit, provide both Notification Class Objects (one for critical, one for non-critical) even if no alarm generation is required at time of installation.
- e. For all intrinsic alarms configure the Limit_Enable Property to set both HighLimitEnable and LowLimitEnable to TRUE. If the specified alarm conditions are for a single-sided alarm (only High_Limit used or only Low_Limit used) assign a value to the unused limit such that the unused alarm condition will not occur.
 - f. For all objects supporting intrinsic alarming, even if no alarm generation is required during installation, configure the following Properties as follows:
 - (1) Notification_Class to point to the non-Critical Notification Class Object in that device.
 - (2) Limit_Enable to enable both the HighLimitEnable and LowLimitEnable
 - (3) Notify_Type to Alarm
 - g. Use of alarm generation types:
 - (1) Only use algorithmic alarm generation when intrinsic alarm generation is not supported by the device or object, or when the specific alarm conditions cannot be implemented using intrinsic alarm generation.
 - (2) Only use remote alarm generation when the alarm cannot be generated using intrinsic or local algorithmic alarm generation on the device containing the referenced property. If remote alarm generation is used, use the same DDC Hardware for all remote alarm generation within a single sequence.

3.1.3.3 Support for Future Alarm Generation

For every piece of DDC Hardware, support future alarm generation capabilities by supporting either intrinsic or additional algorithmic alarming. Provide one of the following:

- a. Support intrinsic alarming for every Object used by the application in that device.
- b. Support additional Event_Enrollment Objects. For DDC hardware controlling a single terminal unit, support at least one additional object. Otherwise, support at least 4 additional Objects. Support additional Event_Enrollment Objects via one of the following:
 - (1) Provide unused Event_Enrollment Objects on that device.
 - (2) Support the DM-OCD-B BIBB and the creation of sufficient Event_Enrollment Objects on that device.
 - (3) Provide one or more devices in the IP network that support the

AE-N-E-B BIBB and have unused Event_Enrollment Objects.

- (4) Provide one or more devices on the IP network that support the AE-N-E-B BIBB, the DM-OCD-B BIBB, and the creation of sufficient Event_Enrollment Objects.

The total number of Event_Enrollment Objects required by the project is the sum of the individual device requirements, and the distribution of Event_Enrollment Objects among devices is not further restricted. (Note this allows a single device to contain many Event_Enrollment Objects satisfying the requirements for multiple devices.)

3.1.3.4 Trend Log Configuration

- a. Configure trends in Trend Log or Trend Log Multiple Objects as indicated on the Points Schedule and as specified.
- b. Configure all trend logs (including any provided to support future trends) to save data on regular intervals using the BUFFER_FULL event to request trend upload from the front end.
- c. Configure Trend Log Objects with a minimum Buffer_Size property value of 1,000 and Trend Log Multiple Objects with a minimum Buffer_Size property value of 1,000 per point trended (for example, a Trend Log Multiple Object used to trend 3 points must have a Buffer_Size Property value of at least 3,000).
- d. Configure a Notification Class Object in devices doing trending (including devices supporting future trends) to handle the BUFFER_FULL event.
- e. When possible, trend each point using an Object in the device containing the point. When it is necessary to trend using a an Object in another device, all trends not on the same Device as the Object being trended must be on a single device (i.e. all Trend Log and Trend Log Multiple Objects used for remote trending within a sequence must be on the same device).
- f. For each trend log, including any trend logs provided to support future trending, configure the following properties as specified:
 - (1) Logging_Type: Set to Polling
 - (2) Stop_When_Full: Set to Wrap Around
 - (3) Buffer_Size: Set to 400 or greater.
 - (4) Notification_Threshold: Set to 90 percent of full
 - (5) Notification_Class: Set to the Notification Class Object in that device
 - (6) Event_Enable: Set to TRUE
 - (7) Log_Interval: Set to 15 minutes.
- g. Future Trending support. Provide support for future trending:
 - (1) Provide one or more devices on the Building Control Network

Backbone IP network which support both the T-VMT-E-B and DM-OCD-B BIBBs for Trend Log Objects. Provide sufficient devices to support the creation of at least one additional Trend Log Object for every terminal unit plus 4 additional Trend Log Objects for every non-terminal unit.

- (2) Provide one additional Trend Log Object for every terminal unit plus 4 additional Trend Log Objects for every non-terminal unit in one or more devices on the Building Control Network Backbone IP network that support the T-VMT-E-B BIBB for later use by the site.
- (3) A combination of these two methods is permitted provided the total required number of Trend Log Objects is met.

3.1.3.5 Overrides

Provide an override for each point shown on the Points Schedule as requiring an override.

Unless otherwise approved, provide Commandable Objects to support all Overrides . With specific approval from the Contracting Officer, Overrides for points which are not hardware outputs and which are in DDC hardware controlling a single terminal unit may support overrides via an additional Object provided for the override. No other means of implementing Overrides may be used.

- a. Where Commandable Objects are used, ensure that WriteProperty service requests with a Priority of 10 or less take precedence over the SEQUENCE VALUE and that WriteProperty service request with a priority of 11 or more have a lower precedence than the SEQUENCE VALUE.
- b. For devices implementing overrides via additional Objects, provide Objects which are NOT Written to as part of the normal Sequence of Operations and are Writable when Out_Of_Service is TRUE and Out_Of_Service is Writable. Use this point as an Override of the normal value when Out_Of_Service is TRUE and the normal value otherwise. Note these Objects may be modified as part of the sequence via local processes, but must not be modified by local processes when Out_Of_Service is TRUE.

3.1.4 BACnet Gateways

The requirements in this paragraph do not themselves permit the installation of hardware not meeting the other requirements of this section. Except for proprietary systems specifically indicated in Section 23 09 00, all control hardware installed under this project must meet the requirements of this specification, including the control hardware providing the network interface for a package unit or split system specified under another section. Only use gateways to connect to pre-existing control devices, and to proprietary systems specifically permitted by Section 23 09 00.

3.1.4.1 General Gateway Requirements

Provide BACnet Gateways to connect non-BACnet control hardware in accordance with the following:

- a. Configure gateways to map writable data points in the controlled equipment to Writable Properties of Standard Objects as indicated in

the Points Schedule and as specified.

- b. Configure gateway to map readable data points in the controlled equipment to Readable Properties of Standard Objects as indicated in the Points Schedule and as specified.
- c. Configure gateway to support the DS-COV-B BIBB for all points mapped to BACnet Objects.
- d. Do not use non-BACnet control hardware for controlling built-up units or any other equipment that was not furnished with factory-installed controls.
- e. Do not use non-BACnet control hardware for system scheduling functions.
- f. Each gateway must communicate with and perform protocol translation for non-BACnet control hardware controlling one and only one package unit or a single non-BACnet system specifically permitted by Section 23 09 00.
- g. Connect one network port on the gateway to the Building Control Backbone IP Network or to a BACnet MS/TP network and the other port to the single piece of controlled equipment or the non-BACnet system specifically permitted by Section 23 09 00..
- h. For gateways to existing package units or simple split systems, non-BACnet network wiring connecting the gateway to the package unit must not exceed 10 feet in length and must connect to exactly two devices: the controlled equipment (packaged unit) or split system interface and the gateway.

-- End of Section --

SECTION 23 09 53.00 20

SPACE TEMPERATURE CONTROL SYSTEMS
02/10, CHG 2: 08/17

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC. (AMCA)

AMCA 500-D (2018) Laboratory Methods of Testing
Dampers for Rating

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING
ENGINEERS (ASHRAE)

ASHRAE FUN IP (2021) Fundamentals Handbook, I-P Edition

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B16.1 (2020) Gray Iron Pipe Flanges and Flanged
Fittings Classes 25, 125, and 250

ASME B16.5 (2020) Pipe Flanges and Flanged Fittings
NPS 1/2 Through NPS 24 Metric/Inch Standard

ASME B16.15 (2018) Cast Copper Alloy Threaded Fittings
Classes 125 and 250

ASME B16.18 (2021) Cast Copper Alloy Solder Joint
Pressure Fittings

ASME B16.22 (2021) Wrought Copper and Copper Alloy
Solder Joint Pressure Fittings

ASME B16.26 (2018) Standard for Cast Copper Alloy
Fittings for Flared Copper Tubes

ASME B16.34 (2021) Valves - Flanged, Threaded and
Welding End

ASME B31.1 (2022) Power Piping

ASME B31.5 (2022) Refrigeration Piping and Heat
Transfer Components

ASME B40.100 (2022) Pressure Gauges and Gauge
Attachments

ASME BPVC (2010) Boiler and Pressure Vessels Code

ASTM INTERNATIONAL (ASTM)

ASTM A126	(2004; R 2023) Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
ASTM B32	(2020) Standard Specification for Solder Metal
ASTM B75/B75M	(2020) Standard Specification for Seamless Copper Tube
ASTM B88	(2022) Standard Specification for Seamless Copper Water Tube
ASTM D635	(2018) Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
ASTM D638	(2014) Standard Test Method for Tensile Properties of Plastics
ASTM D792	(2013) Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM D1238	(2013) Melt Flow Rates of Thermoplastics by Extrusion Plastometer
ASTM D1693	(2015) Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ST 1	(1988; R 1994; R 1997) Specialty Transformers (Except General Purpose Type)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023; ERTA 7 2023; TIA 23-15) National Electrical Code
NFPA 90A	(2024) Standard for the Installation of Air Conditioning and Ventilating Systems

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)

SMACNA 1780	(2002) HVAC Systems - Testing, Adjusting and Balancing, 3rd Edition
SMACNA 1966	(2020) HVAC Duct Construction Standards Metal and Flexible, 4th Edition

U.S. FEDERAL COMMUNICATIONS COMMISSION (FCC)

FCC Part 15 Radio Frequency Devices (47 CFR 15)

UNDERWRITERS LABORATORIES (UL)

UL 508 (2018; Reprint Jul 2021) UL Standard for Safety Industrial Control Equipment

UL 555S (2014; Reprint Oct 2020) UL Standard for Safety Smoke Dampers

UL 916 (2015; Reprint Oct 2021) UL Standard for Safety Energy Management Equipment

1.2 SUBCONTRACTOR SPECIAL REQUIREMENTS

Perform all work in this section in accordance with the paragraph SUBCONTRACTOR SPECIAL REQUIREMENTS in Section 01 30 00 ADMINISTRATIVE REQUIREMENTS. The paragraph specifies that all contract requirements of this section shall be accomplished directly by a first tier subcontractor. No work required shall be accomplished by a second tier subcontractor.

1.3 SYSTEM DESCRIPTION

Provide space temperature control systems complete and ready for operation.

1.4 SYSTEM REQUIREMENTS

Provide control systems composed of any combination of electric, analog electronic or pneumatic devices. Indicated control system devices of a particular type do not intend a requirement for the device unless the requirement is specifically indicated. Requirements apply to field installed control systems.

1.5 CENTRALIZED DIRECT DIGITAL CONTROL (DDC) SYSTEMS

DDC systems are not permitted. Microprocessor-based single-loop controllers, unitary control system, variable-air-volume (VAV) boxes, and room thermostats may be used provided that the devices are manually configurable by the use of device firmware and require no software written by the Contractor for their application and use.

1.6 PERFORMANCE REQUIREMENTS

Provide control systems to maintain the required heating, ventilating, and cooling (HVAC) conditions by performing the functions and sequences of operations indicated. Control systems shall be complete, including all equipment and appurtenances, and ready for operation. Control systems shall be furnished, installed, tested, calibrated, and started up by, or under the supervision of trained technicians certified by the Contractor as qualified and regularly employed in such work. Control system equipment, valves, panels and dampers shall bear the manufacturer's nameplate.

1.7 DESIGN REQUIREMENTS

1.7.1 Control System Diagrams

For each system, indicate HVAC process flow and location of devices relative to flow and to the HVAC control panel, the connections of control devices in control loops, references of control device contacts and device operating coils to line numbers of a ladder diagram and sequencing diagrams showing the operation of valves, dampers, and contacts relative to controller output, and HVAC process variables.

1.7.2 Ladder Diagram

Indicate connections and interlocks to control system devices and other devices such as starters, drives, HVAC control system panels, and HVAC equipment panels. Diagram shall be coordinated by line number and device number with each control system diagram.

1.7.3 Operating Parameters

Indicate operating parameters for devices shown on the control system diagram such as setpoints, ranges, limits, differentials, outside air temperature schedules, contact operating points, and HVAC equipment operating time schedules.

1.7.4 Automatic Control Valve Schedules

Indicate valve size, Cv, flow rate, pressure drop, top size, spring range, positioner range, operating signal characteristics, and power source.

1.7.5 Damper Schedules

Indicate damper sizes, quantities and sizes of actuators, spring ranges, positioner ranges, operating signal characteristics, and power source.

1.7.6 Wiring Diagram

Indicate terminal blocks, wire marker identification, connections to control system devices, external and internal power sources, and connections to external devices, starters, drives, control panels, jumpers, and ground connections.

1.7.7 Compressed Air Station Schematic

Indicate compressors, motors and horsepower rating, voltage, starter, isolators, manual bypasses, tubing sizes, drain piping and drain traps, reducing valves, dryer, manufacturers' names and model numbers, mounting, access, and clearance requirements. Also include control panel schematics for pneumatic control.

1.7.8 Sequence of Operation

Sequence of operation for each HVAC control system coordinated with device identifiers on control system diagram and ladder diagram.

1.7.9 Arrangement Drawing

Arrangement diagram of each HVAC control system panel coordinated with device identifiers on the control system diagram and the ladder diagram.

1.8 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Control System Diagrams for each HVAC system; G

Ladder Diagram; G

Operating Parameters; G

Automatic Control Valve Schedules; G

Damper Schedules; G

Sequence of Operation; G

Arrangement Drawing; G

Wiring Diagram; G

Compressed Air Station Schematic; G

Control Panel Schematics for pneumatic control; G

SD-03 Product Data

Actuators; G

Valves; G

Dampers; G

Fire Protection Devices; G

Sensors; G

Thermostats; G

Sunshields; G

Pressure Switches; G

Indicating Devices; G

Controllers; G

Pressure Gages; G

Control Panels; G

Air Compressor; G

Refrigerated Air Dryer; G

Air Filtration System; G

Compressed Air Station Specialties; G

VAV Terminal Unit Controls; G

SD-06 Test Reports

Commissioning Procedures; G

Calibration Adjustment And Commissioning Reports; G

Site Testing Procedures Identifying Each Item Tested and
Describing Each Test; G

Performance Verification Test plans and procedures; G

SD-07 Certificates

Certification of Completion; G

SD-08 Manufacturer's Instructions

Training Course Documentation; G

SD-10 Operation and Maintenance Data

Space Temperature Control System, Data Package 3; G

Submit in accordance with Section 01 78 23 OPERATION AND
MAINTENANCE DATA.

SD-11 Closeout Submittals

Qualified Service Organization List; G

1.9 QUALITY ASSURANCE

1.9.1 Standard Products

- a. Material and equipment shall be standard products of manufacturers regularly engaged in the manufacturing of such products, using similar materials, design and workmanship. The standard products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year use shall include applications of similarly sized equipment and materials used under similar circumstances.

The 2 years experience must be satisfactorily completed by a product which has been sold or is offered for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures. Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation, for not less than 6000 hours exclusive of the manufacturer's factory tests, can be shown.

- b. The equipment items shall be supported by a service organization.

1.9.2 Nameplates and Tags

- a. Provide nameplates bearing legends as shown and tags bearing device unique identifiers as shown shall have engraved or stamped characters. Nameplates shall be mechanically attached to HVAC control panel doors.
- b. A plastic or metal tag shall be mechanically attached directly to each field-mounted device or attached by a metal chain or wire.
- c. Each airflow measurement station shall have a tag showing flow rate range for signal output range, duct size, and device identifier where shown.

1.9.3 Verification of Dimensions

Contractor shall become familiar with details of work, shall verify dimensions in the field, and shall advise Contracting Officer of any discrepancy before performing work.

1.9.4 Modification of References

Accomplish work in accordance with ASME B31.1, ASME B31.5, NFPA 70, and NFPA 90A, except as modified herein or indicated otherwise for equipment, materials, installation, examination, inspection, and testing. Consider the advisory or recommended provisions to be mandatory, as though the word "shall" had be substituted for the words "should" or "could" or "may," wherever they appear. Interpret reference to "authority having jurisdiction" and "owner" to mean the Contracting Officer.

1.9.5 Site Testing Procedures

Indicate test equipment to be used including manufacturers' names and model numbers, date of last calibration, and accuracy of calibration.

1.9.6 Commissioning Procedures

Define procedures specific to each control system including instructions on how to set control parameters and setpoints, proportional, integral and derivative mode constants, contact output settings, positioner range adjustments, and calibration checks of transmitters

1.9.7 Calibration Adjustment and Commissioning Reports

Submit specific to each HVAC control system, including settings adjustments and results of calibration checks

1.9.8 Space Temperature Control System

In addition to the requirements specified in the paragraph SUBMITTALS, meet the following requirements. Submit Operation and Maintenance Manuals for items of equipment listed under paragraph PRODUCT DATA. Manual shall contain full hardware support documentation, which shall include but not be limited to the following:

- a. General description and specifications

- b. Installation and initial checkout procedures
- c. Detailed electrical and logical description
- d. Troubleshooting procedures, diagrams, and guidelines
- e. Alignment and calibration procedures for components
- f. Preventive maintenance requirements and a maintenance checklist
- g. Detailed schematics and assembly drawings
- h. Spare parts list data, including required tool kits and suggested method of repairs such as field repair, factory repair, or item replacement
- i. Signal identification and timing diagrams
- j. Complete as-built control drawings, schedules, and sequence of operation
- k. Controller configuration and parameter setting procedures
- l. Step-by-step procedures required for each HVAC control systems startup, operation, shutdown, recovery, and fault diagnosis
- m. Manufacturer supplied operator manuals for equipment
- n. Qualified service organization list

PART 2 PRODUCTS

2.1 COMPONENTS

Provide components factory ordered for this project. Rebuilt equipment, warehoused equipment, or earlier generation equipment shall not be acceptable. Electrical, electronic, and electropneumatic devices not located within control panels shall have a NEMA 250 Type 1 enclosure in accordance with NEMA 250 unless otherwise specified. Actuators and positive positioners, and transmitters shall operate within temperature limit ratings of plus 35 to 150 degrees F. Panel mounted instruments shall operate within limit ratings of 35 to 120 degrees F and 10 percent to 95 percent relative humidity, noncondensing. Devices installed outdoors shall operate within limit ratings of minus 35 to 150 degrees F.

2.2 ACTUATORS

Provide pneumatic, electric, or electronic actuators. Actuators shall function as required within 85 to 110 percent of their power supply rating. Actuators shall fail to their spring return positions on signal or power failure unless indicated as timed, power return actuators. Actuators shall have visible position indicators. Where actuators do not have positive spring returns for fail-safe operation, provide capacity tanks, restrictors, check valves, and relays, or reserve power as required to achieve proper timed positioning for up to 4 minutes after primary power failure. Actuators shall open or close the devices to which they are applied within 60 seconds after a full scale signal input change. Pneumatic actuators shall be rated for 25 psig operating pressure except for high pressure cylinder type actuators.

2.2.1 Damper Actuators

Damper actuators shall be rated for at least 125 percent of the motive power necessary to operate the connected damper. The actuator stroke shall be limited by an adjustable stop in the direction of the return stroke. Actuators shall be provided with mounting and connecting hardware.

2.2.2 Valve Actuators

Valve actuators shall be rated for at least 125 percent of the motive power necessary to operate the valves over their full range of operation against the total and differential pressures.

2.2.3 Positive Positioners

Positive positioners shall be pneumatic relays with mechanical feedback mechanisms, adjustable operating ranges, and starting points.

2.3 AUTOMATIC CONTROL VALVES

Provide automatic control valves.

2.3.1 Valve Assembly

Valves shall have stainless steel stems and stuffing boxes with extended necks to clear the piping insulation. Valve bodies shall be designed for not less than 125 psig working pressure or 150 percent of the system operating pressure, whichever is greater. Maximum rated shutoff pressure of the valve shall exceed the rated deadhead pressure of the pump that supplies it. Valve leakage rating shall be 0.01 percent of rated Cv for soft-seated valves and 0.05 percent for metal-to-metal seated valves. Class 125 copper alloy valve bodies and Class 150 steel or stainless steel valves shall conform to ASME B16.5 as a minimum. Components of cast iron valves shall conform to ASTM A126 Class B or C as a minimum.

2.3.2 Butterfly Valve Assembly

Butterfly valves shall be threaded lug type suitable for dead-end service, and for modulation to the fully closed position, with carbon steel bodies or cast iron Class 125 and noncorrosive discs, stainless steel shafts supported by bearings, and EPDM seats suitable for temperatures from minus 20 degrees to plus 250 degrees F. Valves shall have a manual means of operation independent of the actuator.

2.3.3 Two-Way Valves

Two-way modulating valves shall have equal percentage characteristics.

2.3.4 Three-Way Valves

Three-way valves shall provide constant total flow throughout full plug travel.

2.3.5 Duct-Coil and Terminal-Unit-Coil Valves

Control valves with either flare-type or solder-type ends shall be provided for duct or terminal-unit coils. Flare nuts shall be provided for each flare-type end valve.

2.3.6 Valves for Chilled Water, Condenser Water, and Glycol Service

ASME B16.1. Bodies for valves 2 inches and smaller shall be brass or bronze, with threaded-end or union-end connections. Bodies for valves from 2.5 inches and larger shall be cast iron. Bodies for valves 2.5 inches and larger shall have flanged-end connections. Internal valve trim shall be brass or bronze except that valve stems may be Type 316 stainless steel. Water valves shall be sized for a 3 psi differential through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow. Valves 4 inches and larger shall be butterfly valves.

2.3.7 Valves for Hot Water Service

Valves for hot water service below 250 Degrees F shall conform to ASME B16.1. Bodies for valves 2 inches and smaller shall be brass or bronze, with threaded-end or union-end connections. Bodies for valves 2.5 inches and larger shall be cast iron. Bodies for 2.5 inches and larger shall have flanged-end connections. Water valves shall be sized for a 3 psi differential through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow. Internal trim, including seats, seat rings, modulating plugs, and springs, of valves controlling water hotter than 210 degrees F shall be Type 316 stainless steel. Internal trim for valves controlling water 210 degrees F or less shall be brass or bronze. Non-metallic parts of hot water control valves shall be suitable for a minimum continuous operating temperature of 250 degrees F or 50 degrees F above the system design temperature, whichever is higher. Valves 4 inches and larger shall be butterfly valves.

2.3.8 Valves for Steam Service

ASME B16.1. Bodies for valves 1.5 inches and smaller shall be brass or bronze, with threaded or union ends. Bodies for valves 2 to 3 inches inclusive shall be brass, bronze, or cast iron. Bodies for valves 4 inches and larger shall be cast iron. Bodies for 2 inch valves shall have threaded ends. Bodies for valves 2.5 inches and larger shall be provided with flanged-end connections. Internal valve trim shall be Type 316 stainless steel. Steam valves shall be sized for 15 psig inlet steam pressure with a maximum 13 psi differential through the valve at rated flow, except as indicated otherwise.

2.3.9 Valves for High Temperature Hot Water Service

Valves for high temperature hot water service above 250 degrees F. Valve bodies shall conform to ASME B16.34 Class 300. Valve and actuator combination shall be normally closed. Bodies shall be carbon steel, globe type with welded ends on valves one inch and larger. Valves smaller than one inch shall have socket-weld ends. Packing shall be virgin polytetrafluoroethylene (PTFE). Internal valve trim shall be Type 316 stainless steel. Water valves shall be sized for a 3 psi differential pressure through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow.

2.3.10 Valves for Compressed Air Service

Valves used for switching compressed air supplied to pneumatic systems shall be brass body, three-way valves which shall conform to ASME B16.15 Class 250.

2.4 DAMPERS

Provide dampers in air ducts.

2.4.1 Damper Assembly

Damper shall conform to SMACNA 1966. A single damper section shall have blades no longer than 48 inches and shall be no higher than 72 inches. Maximum damper blade width shall be 8 inches. Larger sizes shall consist of a combination of sections. Dampers shall be steel or other materials where indicated. Flat blades shall be made rigid by folding the edges. Provide blades with compressible seals at points of contact. Provide channel frames of dampers with jamb seals to minimize air leakage. Dampers shall not leak in excess of 10 cfm per square foot at 4 inches water gage static pressure when closed. Seals shall be suitable for an operating temperature range of minus 40 degrees F to 200 degrees F. Dampers shall be rated at not less than 2000 fpm air velocity. Moving parts of the operating linkage in contact with each other shall consist of dissimilar materials. Damper axles shall be 0.5 inch minimum plated steel rods supported in the damper frame by stainless steel or bronze bearings. Blades mounted vertically shall be supported by a non-ferrous dissimilar thrust bearings. Pressure drop through dampers shall not exceed 0.05 inch water gage at 1,000 fpm in the wide-open position. Frames shall not be less than 2 inches wide. Dampers shall be tested in accordance with AMCA 500-D.

2.4.2 Operating Links

Operating links external to dampers, such as crankarms, connecting rods, and line shafting for transmitting motion from damper actuators to dampers, shall withstand a load equal to at least twice the maximum required damper-operating force. Rod lengths shall be adjustable. Links shall be brass, bronze, zinc-coated steel, or stainless steel. Mating parts shall consist of dissimilar materials. Working parts of joints and clevises shall be brass, bronze, or stainless steel. Adjustments of crankarms shall control the open and closed position of dampers.

2.5 FIRE PROTECTION DEVICES

Provide smoke detectors in return and supply air ducts on the downstream side of the filters in accordance with NFPA 90A, except as otherwise indicated. Provide UL listed or FM approved detectors for duct installation.

2.5.1 Smoke Detectors

Provide in each air-handling system with supply air capacity greater than 2000 cfm in accordance with NFPA 90A. Locate downstream of the supply air filters and prior to any branch connection in accordance with NFPA 72. Provide in each air-handling system, serving more than one story, and having a return air capacity greater than 15000 cfm in accordance with NFPA 90A. Locate at each story prior to connection to common return and at return connection to air handler prior to any fresh air inlet connection

and prior to any recirculation connection in accordance with NFPA 72. Smoke control and exhaust systems shall have provision for automatic and manual operation by means of a key-operated switch to override any other shutdown features and shall be located adjacent to the fire alarm system control panel .

Provide in each air-handling system with supply air capacity greater than 944 L/s 2000 cfm in accordance with NFPA 90A. Locate downstream of the supply air filters and prior to any branch connection in accordance with NFPA 72.

Provide in each air-handling system, serving more than one story, and having a return air capacity greater than 7079 L/s 15000 cfm in accordance with NFPA 90A. Locate at each story prior to connection to common return and at return connection to air handler prior to any fresh air inlet connection and prior to any recirculation connection in accordance with NFPA 72. Design for detection of abnormal smoke densities by the ionization or photoelectric principle, responsive to both invisible and visible particles of combustion, and not susceptible to undesired operation by changes to relative humidity.

Provide UL listed or FM approved detectors for duct installation. Provide duct detectors with an approved duct housing, mounted exterior to the duct, and with perforated sampling tubes extending across the width of the duct. Provide permanent descriptive zone labels indicating in which air-handling units the detectors in alarm are located.

Provide detectors with a test port , remote keyed test device. Provide control and power modules required for operation of detectors integral with the main building fire alarm control panel. A ground fault or single break or open condition in electrical circuitry to any detector or its control or power units shall cause activation of building fire alarm control panel trouble signals.

Electrical supervision of wiring used exclusively for air-handling unit shutdown is not required provided a break in wiring would cause shutdown of the associated unit. Equipment and devices shall be compatible and operable in all respects with, and shall in no way impair reliability or operational functions of, the existing building fire alarm system. The existing fire alarm control panel was manufactured by .

Smoke control and exhaust systems shall have provisions for automatic and manual operation by means of a key-operated switch to override any other shutdown features and shall be located adjacent to the fire alarm system control panel .

2.5.2 Smoke Dampers and Combination Smoke/Fire Dampers

Smoke dampers and actuator assemblies as required in accordance with NFPA 90A shall meet the Class II leakage requirements of UL 555S. Dampers shall be factory fabricated, galvanized steel or stainless steel with lubricated bearings, linkages, and seals to withstand temperatures from minus 20 to 250 degrees F. Provide replaceable seals. Combination smoke/fire dampers shall have a UL 1.5 hour rating and shall be equipped with electric/thermal links which close the damper at 165 degrees F and then automatically reset after normal temperature is restored by cycling damper actuator. Equip dampers with pneumatic or electric actuators which close smoke dampers tightly when activated. After the smoke has cleared, the dampers shall automatically reset.

2.6 SENSORS

2.6.1 Spans and Ranges

Transmitters shall be calibrated to provide an electric or electronic output signal of 4 to 20 mA electric or electronic and 3 to 15 psi output for pneumatics over the indicated span or range.

- a. Conditioned space temperature, from 50 to 100 degrees F.
- b. Duct temperature, from 40 to 140 degrees F.
- f. Heating hot water temperature, from 100 to 250 degrees F.
- h. Outside air temperature, from minus 30 to 130 degrees F.
- i. Relative humidity, from 0 to 100 percent for high/low limit applications; from 20 to 80 percent for space applications.
- j. Differential pressure for VAV supply duct static pressure from 0 to 2.0 inches water gage.
- l. Electronic airflow measurement station and transmitter, from 125 to 2500 fpm, 1500 to 4500 fpm, or 3000 to 6000 fpm as required by the duct system.

2.6.2 Temperature Sensors

2.6.2.1 Resistance Temperature Detectors (RTD's)

RTD shall be platinum with a tolerance of plus or minus 0.25 percent at 32 degrees F, and shall be encapsulated in epoxy, Series 300 stainless steel, anodized aluminum, or copper. RTD shall be furnished with RTD transmitter as specified, integrally-mounted unless otherwise indicated.

2.6.2.2 Continuous Averaging RTD's

Continuous averaging RTD's shall have a tolerance of plus or minus 1.0 degrees F at the reference temperature, and shall be of sufficient length to ensure that the resistance represents an average over the cross section in which it is installed. Sensing element shall have a bendable copper sheath. Averaging RTD shall be furnished with RTD transmitter as specified, to match the resistance range of the averaging RTD. Element length shall be a minimum of one linear foot per square foot of coil face area.

2.6.2.3 RTD Transmitter

RTD transmitter shall be selected to match the resistance range of the RTD. Transmitter shall be a two-wire, loop-powered device. Transmitter shall produce a linear 4 to 20 mA dc output corresponding to required temperature measurement. Output error shall not exceed 0.1 percent of the calibrated measurement. Transmitter shall include offset and span adjustments.

2.6.2.4 Pneumatic Temperature Transmitter

Transmitting sensing elements shall be bi-metal, averaging element and

capillary, rod and tube, or bulb and capillary. Transmitters shall operate within the range of 40 to 240 degrees F. Provide the following spans and allowable deviations for applications listed.

- a. Room sensors, 25 degrees F, plus or minus 0.5 degrees F
- b. Room, chilled water, dew point, return air sensors, 50 degrees F, plus or minus 0.75 degree F
- c. Outside air, hot water, coil discharge sensors, 100 degrees F, plus or minus 1.0 degree F
- d. High temperature hot water, chilled hot water system sensors, 200 degrees F, plus or minus 2.0 degrees F.

2.6.3 Relative Humidity Instruments

2.6.3.1 Relative Humidity Sensor

Provide relative humidity sensor. Use nonsaturating sensing elements capable of withstanding a saturated condition without permanently affecting calibration or sustaining damage. Sensing elements shall be bulk polymer or thin film polymer. Sensing elements shall have an accuracy of plus or minus 2 percent of full scale within the range of 20 to 80 percent relative humidity. Provide a two-wire, loop-powered transmitter located at the sensing elements to convert the sensing elements output to a linear 4 to 20 mA dc output corresponding to required humidity measurement. Output error shall not exceed 0.1 percent of calibrated measurement. Transmitter shall include offset and span adjustments. Transmitter shall have ability to be calibrated electronically by using a one-point, in-situ method which allows for error correction with a single potentiometer.

2.6.4 Dew Point Instruments

Provide analog salt-phase transition or dual chilled, mirror type sensor. Sensor shall have an allowable deviation of plus or minus one degrees F dew point over the range of 10 to 80 degrees F dew point.

2.6.5 Airflow Sensors

Provide airflow sensors.

2.6.5.1 Electronic Airflow Measurement Stations and Transmitters

- a. Stations shall contain an array of velocity sensing elements and straightening vanes inside a flanged sheet metal casing. Velocity sensing elements shall be RTD or thermistor type, with linearizing means. Sensing elements shall be distributed across the duct cross section in the quantity and pattern set forth for measurements and instruments in accordance with ASHRAE FUN IP and SMACNA 1780, for traversing of ducted airflows. Resistance to airflow through the airflow measurement station shall not exceed 0.08 inch water gage at airflow of 2000 fpm. Station construction shall be suitable for operation at airflows of up to 5000 fpm over a temperature range of 40 to 120 degrees F, and accuracy shall be plus or minus 3 percent over a range of 125 to 2500 fpm scaled to air volume. Use stations if required velocity measurement is below 500 feet per minute.

- b. Transmitters shall produce a linear, temperature compensated 4 to 20 mA dc output corresponding to required velocity pressure measurement. Transmitters shall be a two-wire, loop-powered device. Output error of transmitters shall not exceed 0.5 percent of calibrated measurement. Transmitters shall have offset and span adjustments.

2.6.5.2 Pitot Tube Airflow Measurement Stations and Transmitters

- a. Stations shall contain an array of velocity sensing elements and straightening vanes inside a flanged sheet metal casing. Velocity sensing elements shall be multiple pitot tube type with averaging manifolds. Sensing elements shall be distributed across the duct cross section in the quantity and pattern set forth for measurements and instruments in accordance with ASHRAE FUN IP or SMACNA 1780, for traversing of ducted airflows. Resistance to airflow through the airflow measurement station shall not exceed 0.08 inch water gage at airflow of 2000 fpm. Station construction shall be suitable for operation at airflows of up to 5000 fpm over a temperature range of 40 to 120 degrees F, and accuracy shall be plus or minus 3 percent over a range of 500 to 2500 fpm scaled to air volume. Do not use stations if required velocity measurement is below 500 feet per minute.
- b. Transmitters shall produce a linear 4 to 20 mA dc output corresponding to the required velocity pressure measurement. Each transmitter shall have a low-range differential pressure sensing element and a square root extractor. The transmitter shall be a two-wire, loop powered device. Sensing element accuracy shall be plus or minus 1 percent of full scale, and overall transmitter accuracy shall be plus or minus 0.25 percent of the calibrated measurement. Each transmitter shall have offset and span adjustments.

2.6.6 Pressure Sensors

Provide electronic pressure sensor and transmitter. Sensor shall be a pressure transmitter with an integral sensing element. Sensor over pressure rating shall be 25 psig above its normal operating range. Sensing element accuracy shall be plus or minus one percent of full scale. Transmitter accuracy shall be plus or minus 0.1 percent of the calibrated measurement. Transmitter shall be a two-wire, loop-powered device. Transmitter shall produce a linear 4 to 20 mA dc output corresponding to required pressure measurement. Transmitter shall have offset and span adjustments.

2.7 THERMOWELLS

Provide brass or Series 300 stainless steel thermowells with threaded brass plug and chain, 2 inch lagging neck and extension type well, and inside diameter and insertion length as required for the application. Provide thermowells for immersion sensors with conducting material inside the well.

2.8 THERMOSTATS

Provide thermostats.

2.8.1 Ranges

Thermostat ranges shall be selected so that the setpoint is adjustable without tools between plus or minus 10 degrees F of the setpoint indicated.

2.8.2 Nonmodulating Electric Room Thermostats

Contacts shall be single-pole double-throw (SPDT), hermetically sealed, and wired to identified terminals. Maximum differential shall be 2 degrees F. Thermostat covers shall consist of locking metal or heavy-duty plastic, and shall be capable of being locked by an Allen wrench or special tool. Thermostats shall have manual switches as required by the application and a minimum range of 55 to 90 degrees F.

2.8.3 Microprocessor-Based Room Thermostats

Microprocessor-based room thermostats shall have built-in keypads for scheduling of day and night temperature settings. Access to the scheduling mode shall be by password control code. When out of the scheduling mode, thermostats shall have continuous 12-hour time display, with AM and PM indication, continuous display of day of the week, and either continuous display of room temperature with display of temperature setpoint on demand, or continuous display of temperature setpoint with display of room temperature on demand. In the programmable mode, use the display for setting and interrogating time program ON-OFF setpoints for each day of the week. The time program shall allow two separate temperature setback intervals per day. Thermostats shall have a means for temporary and manual override of program schedule, with automatic program restoration on the following day. Thermostats shall have a replaceable battery to maintain timing and to maintain the schedule in memory for one year in the event of a power outage. Maximum differential shall be 2 degrees F. Where used for heat pump applications, thermostat shall have an emergency heat switch.

2.8.4 Nonmodulating Capillary Thermostats and Aquastats

- a. Thermostat shall have a capillary length of at least 5 feet, adjustable direct reading scales for both setpoint and differential, and a differential adjustable from 6 to 16 degrees F.
- b. Aquastats shall be strap-on type, with 10 degrees F fixed differential.

2.8.5 Low-Temperature Protection Thermostats (Freezestats)

Low-temperature protection thermostats shall be manually reset low-temperature safety thermostats, with NO and NC contacts or a two-position pneumatic output signal and a 20 foot element which shall respond to the coldest 18 inch segment.

2.8.6 Modulating Capillary Thermostats

Thermostats shall have either one output signal, two output signals operating in unison, or two output signals operating in sequence, as required for the application. Thermostats shall have adjustable throttling ranges of 4 to 8 degrees F for each output.

2.8.7 Modulating Pneumatic Room Thermostats

Two-temperature combination thermostats shall be adjustable proportioning type with dual setpoints containing two temperature sensing elements: one for heating control and one for cooling control; two for heating control or two for cooling control. Changeover for two-temperature combination thermostats shall be accomplished by a change in control air supply pressure which selects proper setpoint and proper controller action. Single-temperature thermostats shall be adjustable proportioning type with one temperature sensing element: one setpoint and proper controller action. "Dead-band" thermostats shall have one adjustable proportioning type controller with two setpoints, adjustable dead-band, and one controller output or two adjustable proportioning type controllers mounted on a common backplate with two setpoints, adjustable dead-band, and two controller outputs. Temperature sensing elements shall be selected for proper controller action. Individual temperature-sensing elements shall have a separate adjustable throttling range of 2 to 10 degrees F; thermostat shall have a minimum range of 55 to 90 degrees F and minimum safe air input pressure of 25 psig. Dead-band setting shall have a minimum adjustable range of 4 to 15 degrees F. Room thermostat shall have concealed setpoint dial, aspirator type wall box with flush plate and locking screws, and plug-in gage ports.

2.8.8 Modulating, Insertion, Immersion, & Averaging Pneumatic Thermostats

Thermostats shall be two-pipe, pilot-operated type with pneumatic feedback, proportional action and shall have an adjustable throttling range of 2 to 100 degrees F with a minimum range of 10 to 250 degrees F. Averaging elements shall be 1 foot in length for each 4 square feet of ductwork cross-sectional area with a minimum length of 8 feet.

2.8.9 Nonmodulating Pneumatic Thermostats

Thermostats shall have integral positive acting relays, zero or maximum output pressure. Remote element thermostats shall have standard or averaging bulbs. Averaging bulbs shall be one foot in length for each 4 square feet of ductwork cross-sectional area and a minimum length of 8 feet. Differential ranges shall be field adjustable. Remote element thermostat differential range shall be 2 to 25 degrees F with minimum control ranges of minus 10 to plus 250 degrees F. Room thermostat differential range shall be 2 to 10 degrees F with minimum control ranges of 55 to 90 degrees F.

2.9 SUNSHIELDS

Provide sunshields for outside air temperature sensing elements to prevent the sun from directly striking temperature sensing elements. Provide sunshields with adequate ventilation so that the sensing element responds to the ambient temperature of surroundings. The top of each sunshield shall have galvanized metal or aluminum rainshield projecting over the face of the sunshield. Sunshields shall be painted white or shall be unpainted aluminum.

2.10 PRESSURE SWITCHES AND SOLENOID VALVES

Provide pressure switches and solenoid valves.

2.10.1 Pressure Switches

Switches shall have an adjustable setpoint with visible setpoint scale. Range shall be as indicated. Differential adjustment shall span 20 to 40 percent of the range of the device.

2.10.2 Differential Pressure Switches

Switches shall be an adjustable diaphragm-operated device with two SPDT contacts, with taps for sensing lines to be connected to duct pressure fittings designed to sense air pressure. Fittings shall be angled-tip type with tips pointing into the airstream. Range shall be 0.5 to 6 inches water gage. Differential shall be a maximum of 0.15 inch water gage at the low end of the range and 0.35 inch water gage at the high end of the range.

2.10.3 Pneumatic Electric (PE) Switches

Switches shall have an adjustable setpoint range of 3 to 20 psig, and differential adjustable from 2 to 6 psi.

2.10.4 Solenoid Operated Pneumatic (EP) Valves

Valves shall have three-port operation: common, normally open, and normally closed. Valves shall have an outer cast aluminum body. The air connection shall be a 1/4 inch NPT threaded connection. Valves shall be rated for 50 psig where used in a control system which operates at 25 psig or less, or 150 psig where used in a control system which operates in the range of 25 to 100 psig.

2.11 INDICATING DEVICES

Provide indicating devices.

2.11.1 Thermometers

- a. Thermometers for insertion in ductwork and piping systems shall have brass, malleable iron, or aluminum alloy case and frame, clear protective face, and permanently stabilized glass tube with an indicating fluid column, white face, black numbers, and a 9 inch scale.
- b. Thermometers for piping systems shall have rigid stems with straight, angular, or inclined pattern.
- c. Thermometer stems shall have expansion heads as required to prevent breakage at extreme temperatures. On rigid stem thermometers, the space between bulb and stem shall be filled with a heat transfer medium.
- d. Air duct thermometers shall have perforated stem guards and 45 degree adjustable duct flanges with locking mechanisms.
- e. Averaging thermometers shall have 3.5 inch (nominal) dial, with black legend on white background, and pointer traveling through a 270 degree arc.
- f. Thermometers shall have an accuracy of plus or minus one percent of scale range. Thermometers shall have the following ranges:

- (1) Mixed air temperature: 0 to 100 degrees F in 1 degree F graduations.
- (2) Return air temperature: 0 to 100 degrees F in 1 degree F graduations.
- (3) Cooling coil discharge temperature: 0 to 100 degrees F in 1 degree F graduations.
- (4) Heating coil discharge temperature: 30 to 180 degrees F in 2 degree F graduations.
- (5) Hydronic heating systems below 220 degrees F: 40 to 240 degrees F in 2 degree graduations.
- (6) Chilled water temperature: 0 to 100 degrees F in one degree F graduations.
- (7) Condenser water temperature: 40 to 140 degrees in one degree F graduations.
- (8) Glycol temperature: 0 to 100 degrees F for cooling service in one degree F graduations, and 40 to 240 degrees F for heating service in 2 degree F graduations.
- (9) High temperature hot water: 100 to 550 degrees F in 5 degree F graduations.

2.11.2 Pressure Gages

Provide pressure gages with gage cock, snubber, and syphon.

- a. ASME B40.100. Gages shall be 2 1/2 inch (nominal) size, back-connected, suitable for field or panel mounting as required, shall have black legend on white background, and shall have a pointer traveling through a 270 degree arc. Accuracy shall be plus or minus 3 percent of scale range.
- b. Gages for indicating signal output to pneumatic actuators and main air gages shall have scale of 0 to 30 psig in 1 psig graduations.
- c. Gages for air storage tanks and for use before and after dirt and oil filters or dryers, shall have a scale of 0 to 160 psig with 2 psig graduations.
- d. Gages for hydronic system applications shall have ranges and graduations as indicated.
- e. Pneumatic transmission receiver gages shall have a range to match the respective transmitters.

2.12 LOW-DIFFERENTIAL PRESSURE GAGES

Gages for low-differential pressure measurements shall be 4 1/2 inch (nominal) size with two seats of pressure taps, and shall have a diaphragm-actuated pointer, white dial with black figures, and pointer zero adjustment. Gages shall have ranges and graduations as indicated. Accuracy shall be plus or minus 2 percent of scale range.

2.13 CONTROLLERS

2.13.1 Single-Loop Controllers

2.13.1.1 Controller Features

Controller shall be a microprocessor-based, single-loop device that does not require Contractor-generated software. Controller shall conform to FCC Part 15. Controller panel cutout shall be 3.62 by 3.62 inches. Controller shall have field selectable range for process variables, a remote setpoint analog input and analog output with adjustable high and low end limits, and proportional control manual reset adjustment. Analog output shall result from PID control. Analog output shall be configurable as direct acting and reverse acting. Controller shall have keyboard, display, auto/manual selection for control of analog output, and remote setpoint adjustment/local setpoint adjustment selection. Controller shall have adjustable high-end and low-end limits, ratio, and bias adjustments on remote setpoint input; operator initiated self-tune/manual-tune selection, anti-reset wind-up feature, and two configurable independent SPDT with adjustable system contact closure outputs. Controller shall be configurable to power-up in manual with local setpoint control, in automatic with local setpoint control, and in automatic with remote setpoint control. Contact closures shall be activated by a process variable and by a process variable deviation from setpoint as configured. The range of hysteresis adjustment shall not be smaller than 1 percent to 5 percent of process variable input span. Controller shall power the analog output loop to 20 mA where connected to a load of 600 ohms. Controller shall have 5-year battery backup or shall have nonvolatile memory to store operating parameters.

2.13.1.2 Controller Parameter Input and Display

Control parameters shall be entered and displayed directly, in the correct engineering units, through a series of keystrokes on a front panel display with a 3 1/2-digit, seven-segment display, with decimal point and polarity indication. Use of the display shall allow manual interrogation of setpoint, mode constants, and values of process variables and outputs.

2.13.1.3 Controller Electrical Requirements

Controller shall be powered by 120 Vac. Controller shall provide electrical noise isolation, not less than 100 dB at 60 Hz common mode rejection ratio, and not less than 60 dB at 60 Hz normal mode rejection ratio between ac power line and process variable input, remote setpoint input, and output signals.

2.13.1.4 Controller Accuracy

Controller shall have an accuracy of plus or minus 0.30 percent of input span, plus or minus one digit.

2.13.1.5 Controller Self Tuning

Controller self-tuning operation shall apply proportional, integral, and derivative modes of control; mode constants shall be modified as required. Self tuning shall only operate when selected from the front panel.

2.13.1.6 Controller Manual Tuning

Controller manual tuning operation shall provide proportional, integral, and derivative control modes, or any combination thereof, by means of individual mode constant adjustments. Adjustments shall be set for the appropriate value if a particular control mode action is desired, or to zero for the particular mode not desired. The proportional mode constant shall be adjustable from 0 to 200 percent of input signal range; the integral mode constant shall be adjustable from 0 to 20 repetitions per minute; and the derivative mode constant shall be adjustable from 0 to 5 minutes.

2.13.2 Pneumatic Controllers

Controllers shall be two-pipe devices which use main air supplied to controller and pneumatic relay to produce the controller output signal. Controllers shall have field selectable local and remote adjustable setpoints, and an adjustable proportional band for analog (proportional) control or an adjustable differential for binary (two-position or floating) control. Controllers shall have single- or dual-input ports as required for the application and field selectable direct or reverse action for inputs. Dual input controllers shall have adjustable secondary input authority. Controllers shall have integral gage or test connections for testing or indication of input and output signals.

2.13.3 Analog Electronic Controllers

Controllers shall be solid-state electronic devices which sense the difference between input sensor analog values (resistance or voltage) and setpoint adjustment analog values (resistance or voltage), and shall amplify the difference signal to provide the output signal. Controllers shall include the following:

- a. Proportional band: 2.5 to 33 percent of input device span.
- b. Authority: minimum of 33 to 200 percent.
- c. Inputs: thermistor, resistance, transmitter, or output of other electronic controllers.
- d. Outputs: within the range of minus 5 to 20 Vdc or a 4 to 20 mA dc current loop.
- e. Remote setpoint adjustment (SPA): plus or minus 10 percent of input device span.

2.13.4 Unitary Control Systems

Unitary control systems shall be energy-efficient, micro-processor-based temperature controllers and associated devices that do not require Contractor-generated software. Provide control systems with integral or remote sensor as indicated. Controllers shall operate heating, cooling, and ventilating modes with independent occupied and unoccupied settings for each of 7 consecutive days. Cooling shall be controlled in two steps and heating shall be controlled in two steps with modulating control provided for the ventilation mode. Provide temperature changeover control to limit the ventilation mode when outdoor air temperature is not sufficiently low for "free-cooling." Provision shall be made for automatic changeover between heating and cooling modes, providing a one minute

minimum time delay between the start and stop operation of heating and cooling stages upon startup and after power failure to prevent short cycling and power surges. Provide an optimum startup program to minimize warm-up or cool-down periods prior to the occupied mode. Outside air dampers shall be closed during the optimum startup program unless outside air is beneficial for cool-down in lieu of mechanical cooling. Fan shall operate continuously during the occupied mode and shall cycle during the unoccupied mode for heating or cooling. Provide battery backup to retain programs and maintain clock operation for 48 hours minimum during power outages. Controller shall have a self-diagnostic program to indicate errors and locking covers to prevent unauthorized program entries. Provide a convenient means to restore the occupied mode of operation for a minimum 2-hour period without removing covers. An indexing switch shall allow operation in a continuous unoccupied mode during abnormal periods without changing normal programs. Servicing tool required to place the unitary control system in use shall be a hand-held device used to adjust and monitor setpoints, controlled device positions, input sensor values, and other control system parameters.

2.13.5 Pneumatic Low-Range Pressure Controllers for Ductwork Applications

Controllers shall provide two-pipe, pilot-operated control with pneumatic feedback and proportional action. Sensing elements shall be differential type with pressure ranges appropriate for intended service. One element shall measure the variable while the other element measures the standard reference. Static pressure controllers shall have slack diaphragms with standard ranges between 0 to 6 inches water gage and an adjustable throttling range of 0.02 to 0.5 inch water gage. Sensing element shall be mountable in ductwork and shall measure static pressure without pulsations.

2.13.6 Pneumatic Differential Pressure Controllers for Liquid Applications

Differential pressure controllers shall have a minimum range of 0 to 50 psig or 0 to 250 psig as specified or required for the application and shall have an adjustable throttling range of 1 to 25 psig. Sensing element shall be filled diaphragm type with three-valve manifold for isolation and nulling. Provide syphons and pressure snubbers.

2.14 CONTROL DEVICES AND ACCESSORIES

Provide control devices and accessories.

2.14.1 Function Modules

Function modules shall accept mA dc analog input signals to produce analog output signals or contact output signals. Modules shall have zero and span adjustments for analog outputs, and setpoint adjustments for contact outputs.

2.14.1.1 Minimum Position Switches and Temperature Setpoint Devices

Minimum position switches and temperature setpoint devices shall accept manual input and shall produce steady analog output. Switches and devices shall be suitable for recessed wall mounting or panel mounting and shall have a graduated dial.

2.14.1.2 Signal Inverter Modules

Signal inverter modules shall accept analog input signal and produce

analog output signal that linearly reverses the direction of signal change of input versus output.

2.14.1.3 High-Low Signal Selector Modules

High-low signal selector modules shall accept analog input signals and select either the highest or the lowest input signal as the output signal.

2.14.1.4 Sequencer Modules

Sequencer modules shall provide fixed time delayed sequencing of one or more contact transfers from an analog input signal. Sequencers shall return contacts to their zero input signal condition when power is interrupted.

2.14.2 Relays

Relays shall be two-pole, double-throw (DPDT) with a 10-ampere resistive rating at 24 Vac, and shall have an enclosed coil. Provide with a light indicator which is lit when the coil is energized and is not lit when the coil is not energized.

2.14.3 Time-Delay Relays

Time-delay relays shall be DPDT with octal connectors and dust covers. The adjustable timing range shall be 0 to 3 minutes .

2.14.4 Time Clocks

Time clocks shall be a 24-hour, 365-day programmable timing device with two independently timed circuits. Clocks shall have a manual scheduling keypad and alphanumeric display of timing parameters. Timing parameters shall include Gregorian calendar date for month, day and day-of-month indication; and 24-hour time-of-day display, with one-minute resolution for programming the ON and OFF times for each circuit. Circuits shall have programmable timed override from 1 to 99 minutes. Clocks shall have capacity for programming four ON events and four OFF events for each circuit. Programmed events shall be assignable to a 365-day schedule. Clocks shall have automatic standard time and daylight saving time adjustments, keyed to input of appropriate dates. Provide clocks with 4-day battery backup.

2.14.5 Override Timer

Override timers shall be manually set, mechanically driven timers, or electronic timers, without a "hold" feature. Time intervals shall be selectable for up to 12 hours of operation and shall expire unless reset.

2.14.6 Current-to-Pneumatic (IP) Transducers

Transducers shall be two-wire transmitters which convert an input signal to 3 to 15 psig or 15 to 3 psig pneumatic output, with a conversion accuracy of plus or minus 2 percent of full scale, including linearity and hysteresis. Air consumption shall not be greater than 0.25 scfm.

2.14.7 Regulated Power Supplies

Power supplies shall provide a 24-Vdc linear supply at not less than 2 amperes, with regulation to 0.05 percent of output voltage. Power

supplies shall have a fused input, and shall be protected from voltage surges and power-line transients. Power supply output shall be protected against overvoltage and short circuits. Power supply loading shall not be greater than 1.2 amperes.

2.14.8 Transformers

UL 508 and NEMA ST 1 as applicable. Transformers, other than transformers in bridge circuits, shall have primaries wound for available voltage and secondaries wound for correct control circuit voltage. Transformers shall be sized so that connected loads equal 80 percent of rated capacity. Transformers shall be enclosed in rustproof, galvanized steel cabinets with conduit connections. Disconnect switch shall be provided on the primary side, and a fuse cutout on the secondary side. For systems serving , provide backup power supply including transformers connected to the emergency power source . Provide for automatic switchover and alarm upon failure of primary control circuit.

2.14.9 Pilot Lights and Manual Switches

Device illumination shall be by light-emitting diode (LED) or neon lamp. Switches shall have operating levers and index plates showing switch positions and names of apparatus controlled or other appropriate designations.

2.15 HVAC SYSTEM CONTROL PANELS

Provide HVAC system control panels.

2.15.1 Panel Assembly

Panel shall be fabricated for bottom entry connection for control system electric power, control system main air source, control system wiring, pneumatic tubing, interconnection of control systems, interconnection of starters, and external shutdown devices. Panel shall have an operating temperature rise of not greater than 20 degrees F above an ambient temperature of 100 degrees F.

2.15.2 Panel Electrical Requirements

Control panel shall be powered by nominal 120 Vac terminating at panel on terminal blocks. Instrument cases shall be grounded. Interior and exterior panel enclosures shall be grounded.

2.15.3 Enclosures

Enclosures for each panel shall be a single door, wall-mounted box conforming to NEMA 250 with a continuous hinged and gasketed exterior door with a print pocket, key lock, and interior back panel. Inside finish shall be white enamel, and outside finish shall be gray primer over phosphatized surfaces.

2.15.4 Mounting and Labeling

Provide pilot lights, switches, panel-mounted control devices, and pressure gages shall be mounted on the door. Power conditioners, fuses, and duplex outlets shall be mounted on the interior of the cabinet. Other components housed in the panel shall be mounted on the interior back panel surface of the enclosure and shall be identified by plastic or metal

nameplates which are mechanically attached to the panel. Lettering shall be cut or stamped into the nameplate to a depth of not less than 1/64 inch, and shall have contrasting color, produced by filling with enamel or lacquer or by use of laminated material. Painting of lettering directly on the surface of the door or interior back panel is not permitted.

2.15.5 Wiring and Tubing

- a. Pneumatic device inputs and outputs shall be piped to bulkhead fittings in the bottom of the panel with a 2 inch loop to facilitate replacement. Electric, electronic, and electropneumatic device signals entering and leaving the panel shall be wired to identified terminal blocks.
- b. Wiring shall be installed in wiring ducts so that devices can be added or replaced without disturbing existing wiring that is not affected by the change. Wiring to single-loop controllers shall have a 4 inch wiring loop in the horizontal wiring duct at each wiring connection. There shall be no wiring splices within the control panel. Interconnections required for power or signals shall be made on device terminals, if available, or panel terminal blocks, with not more than two wires connected to each terminal.
- c. Instrument signal grounds at the same reference level shall end at a grounding terminal connected to a common ground point for that level. Wiring shield grounds at the same reference level shall end at a grounding terminal connected to a common ground point for that level. Grounding terminal blocks shall be identified by reference level.
- d. Wiring connected to controllers shall be identified by function and polarity, e.g., process variable input and remote setpoint input and output.

2.16 COMPRESSED AIR STATIONS

Provide compressed air stations.

2.16.1 Air Compressor Assembly

- a. Compressor shall be equipped with an electric motor with a totally enclosed belt guard, operating pressure switch, safety relief valves, gages, intake filter, and intake silencer. Compressor shall have combination type magnetic starter with undervoltage protection and thermal overload protection for each phase. Compressor shall be supported by a steel base mounted on an air storage tank. Air compressor shall be sized to supply compressed air required by the control system while operating not more than one-third of the time.
- c. Compressed air storage tank shall be fabricated for working pressure of not less than 200 psig, and constructed and certified in accordance with ASME BPVC. Tank shall be of sufficient volume so that no more than six compressor starts per hour are required with the starting pressure switch differential set at 20 psi differential. Tank shall be provided with an automatic condensate drain trap with a manual override feature.

2.16.2 Compressed Air Station Specialties

- a. Pressure regulator and refrigerated air dryer shall be provided in the air outlet line of the air storage tank. Dryer shall be sized for full air delivery capacity of compressor. Air shall be dried at a pressure of not less than 70 psig to a temperature not greater than 35 degrees F. Dryer shall be provided with an automatic condensate drain trap with a manual override feature.
- b. Two parallel combination dirt and coalescing type oil filters with shutoff valves and pressure regulators shall be provided in the dryer discharge. Air filtration system shall be rated for full delivery capacity of compressor. Filter shall be 100 percent efficient for particle diameters down to 0.3 microns. Filter bowl shall be rated for 150 psig maximum working pressure. One of the filters shall serve as a standby. Pressure regulator and safety valve shall be provided downstream of the filter.
- c. Flexible pipe connectors shall be designed for 150 psi and 250 degrees F service, and shall be constructed of rubber, tetrafluoroethylene resin, or braided corrosion-resistant steel, bronze, monel, or galvanized steel. Connectors shall be suitable for service intended and may have threaded or soldered ends. Length of connectors shall be as recommended by the manufacturer for service intended.
- d. Vibration isolation units shall be standard products with published loading ratings, and shall be single rubber-in-shear, double rubber-in-shear, or spring type.

2.17 ELECTRONIC VARIABLE AIR VOLUME VAV TERMINAL UNIT CONTROLS

Provide electronic VAV terminal unit controls.

2.17.1 VAV Terminal Units

VAV terminal units shall be as specified in Section 23 30 00 HVAC AIR DISTRIBUTION.

2.17.2 Terminal Unit Controls

- a. UL 916 and FCC Part 15. Controls for pressure independent boxes shall consist of a velocity sensing device in the primary air entering box, a room temperature sensing element, a damper actuator, and an adjustable microprocessor-based VAV box controller. Controls shall operate a damper for cooling and a duct coil for heating. Actuator shall open or close the device to which it is applied within 6 minutes.
- b. Controls for pressure independent boxes with recirculating fans shall consist of a velocity sensing device in the primary air entering the box, a room temperature sensing element, an adjustable microprocessor-based VAV box controller, a damper with actuator, and a duct pressure switch to operate the recirculation fan. Controller shall operate the damper for cooling and the recirculating fan and duct coil for heating.
- c. One hand-held communication and programming device with an instruction manual, plus one additional hand-held communication

device and instruction manual per 100 terminal units, shall be provided. Communication and programming device shall connect directly to the controller or to a jack at the room temperature sensing element location. Communication and programming device shall be used to read and set minimum velocity, maximum velocity, heating setpoint, and cooling setpoint, and to read air velocity and space temperature.

2.18 CONTROL TUBING AND WIRING

Provide HVAC control tubing and wiring.

2.18.1 Tube and Fittings

2.18.1.1 Copper Tubing

ASTM B75/B75M or ASTM B88. Tubing 0.375 inch outside diameter and larger shall have a minimum wall thickness equal to ASTM B88, Type M. Tubing less than 0.375 inch outside diameter shall have a minimum wall thickness of 0.025 inch. Concealed tubing shall be hard or soft copper; multiple tubing shall be racked or bundled. Exposed tubing shall be hard copper; rack multiple tubing. Tubing for working pressures greater than 30 psig shall be hard copper. Bundled tubing shall have each tube numbered each six feet minimum. Racked and individual tubes shall be permanently identified at each end. Fittings shall be solder type ASME B16.18 or ASME B16.22, using ASTM B32, Plumbing Code approved lead-free solder, or compression type ASME B16.26.

2.18.1.2 Polyethylene Tubing

Polyethylene tubing shall be provided only for systems with working pressure of 30 psig or less. Provide flame-resistant, multiple polyethylene tubing in flame-resistant protective sheath with Mylar barrier, or unsheathed flame-resistant polyethylene tubing in rigid metal, intermediate metal, or electrical metallic tubing conduit for areas where tubing is exposed. Single, unsheathed, flame-resistant polyethylene tubing may be used where concealed in walls or above ceilings and within control panels, except prohibited in crawl spaces, attics, and above-ceiling spaces that are vented to the outdoors. Do not provide polyethylene tubing for smoke removal systems. Number each tube in sheathing each two feet minimum. Permanently identify unsheathed tubing at each end. Provide compression or barbed push-on type fittings. Extruded seamless polyethylene tubing shall conform to the following:

- a. Minimum burst pressure requirements: 100 psig at 75 degrees F to 25 psig at 150 degrees F.
- b. Stress crack resistance: ASTM D1693, 200 hours minimum.
- c. Tensile strength (minimum): ASTM D638, 1100 psi.
- d. Flow rate (average): ASTM D1238, 0.30 decigram per minute.
- e. Density (average): ASTM D792, 57.5 pounds per cubic feet.
- f. Burn rate: ASTM D635.

2.18.2 Wiring

- a. Terminal blocks shall be insulated, modular, feed-through, clamp style with recessed captive screw-type clamping mechanisms. Terminal blocks shall be rail mounted, and shall have end plates, partition plates or enclosed sides for separation.
- b. Control wiring for 24-V circuits shall be 18 AWG minimum and shall be rated for 300-V service.
- c. Wiring for circuits operating at more than 100 V shall be 14 AWG minimum and shall be rated for 600-V service.
- d. Analog signal wiring circuits within control panels shall not be less than 20 AWG and shall be rated for 300-V service.
- e. Instrumentation cable shall be 18 AWG, stranded copper, single or multiple twisted, minimum 2-inch lay of twist, 100 percent shielded pairs, and shall have 300-V insulation. Each pair shall have a 20-AWG tinned copper drain wire, individual pair, and overall insulation. Cables shall have an overall aluminum polyester or tinned overall copper cable shield tape, 20-AWG tinned-copper cable drain wire, and overall cable insulation.
- f. Nonconducting wiring ducts in control panels shall have slotted side snap-on covers, fittings for connecting ducts, mounting clips for securing ducts, and wire retaining clips.

PART 3 EXECUTION

3.1 INSTALLATION

Perform installation under the supervision of competent technicians regularly employed in the installation of control systems. Provide components for a complete and operational control system. Provide control system complete and ready for operation, as specified and indicated. Provide dielectric isolation where dissimilar metals are used for connection and support. Penetrations through and mounting holes in the building exterior shall be watertight. Control system installation shall provide adequate clearance for control system maintenance by maintaining access spaces between coils, to mixed-air plenums, and as required to calibrate, remove, repair, or replace control system devices. Control system installation shall not interfere with the clearance requirements for mechanical and electrical system maintenance. Install devices mounted in or on piping or ductwork, on building surfaces, in mechanical and electrical spaces, or in occupied space ceilings in accordance with manufacturer's recommendations and as indicated on contract documents. Provide control devices to be installed in piping and ductwork with required gaskets, flanges, thermal compounds, insulation, piping, fittings, and manual valves for shutoff, equalization, purging, and calibration. Certify that installation of control system is complete and technical requirements of this section have been met.

3.1.1 Sensors

Provide sensors in locations to sense the appropriate condition. Install sensor and transmitter where easily accessible and serviceable without special tools. Sensors shall be calibrated to the accuracy specified in the contract, and operate correctly when installed. Do not install

sensors designed for one application in the place of another application (e.g., replacing a duct sensor with a room sensor).

3.1.1.1 Room Sensors

Provide on interior walls to sense average room conditions. Avoid locations which may be covered by office furniture. Do not mount room sensors on exterior walls if other locations are available. Mount centerline of sensor 5 feet above finished floor.

3.1.1.2 Duct Temperature Sensors

Provide sensors in ductwork in general locations as indicated. Select specific sensor location within duct to accurately sense appropriate air temperatures. Locate sensor connection boxes in position not obstructed by ducts or equipment. Install gaskets between sensor housing and duct wall. Seal duct and insulation penetrations. Install duct averaging sensors between two rigid supports in serpentine position to sense average conditions. Sensor shall have a total minimum length of one linear foot per 4 square feet of duct area. Sensor shall be mounted a minimum of 3 inches from outside wall surface. Thermally isolate temperature sensing elements from supports. Provide duct access doors to averaging sensors.

3.1.1.3 Immersion Temperature Sensors

Provide thermowells for sensors measuring temperatures in liquid applications or pressure vessels. Locate wells to sense continuous flow conditions. Do not install wells using extension couplings. Where piping diameters are smaller than the length of the wells, provide wells in piping at elbows to effect proper flow across entire area of the well. Wells shall not restrict flow area to less than 70 percent of pipe area. Increase piping size as required to avoid restriction. Temperature sensors shall be installed in thermowells with thermal transmission material to speed the response of temperature measurement. Provide thermowells with sealing nuts to contain thermal transmission material.

3.1.1.4 Strap-on Temperature Sensors

Strap-on temperature sensors, using helical screw stainless steel clamps, shall be permitted on new hot water piping for on-off operation, and for existing hot water piping sizes not greater than 3 inches. Clean the pipe to bright metal. Insulate strap-on bulb and pipe after installation. Provide other liquid temperature sensors with thermowells. Provide NEMA 250 Type 4 enclosures for outdoor installations. Provide brushed aluminum or brushed stainless steel enclosures for sensors located in finished spaces.

3.1.1.5 Outside Air Temperature Sensors

Provide outside air temperature sensor on north side of building, away from exhaust hoods, air intakes, and other areas which may affect temperature readings. Install sunshields to protect outside air temperature sensor from direct sunlight.

3.1.1.6 Low-Temperature Protection Thermostats (Freezestats)

Provide thermostat for each 80 square feet of coil-face area to sense the temperature at location indicated. Install thermostat sensing element in serpentine pattern.

3.1.2 Thermometers

Provide thermometers which are installed in liquid systems in thermowells with thermal transmitting materials within the well to speed the response of temperature measurement.

3.1.3 Pressure Sensors

3.1.3.1 Duct Static Pressure

Duct static pressure sensor shall be located where indicated on drawings. If no location is indicated, it should be located approximately two-thirds of distance from supply fan to the end of duct with greatest pressure drop.

3.1.3.2 Steam Pressure

Provide snubbers and isolation valves on steam pressure sensing applications.

3.1.4 Pressure Gages

Provide snubbers for gages in piping systems subject to pulsation. Gages for steam service shall have pigtail fittings with cocks. Install pressure gages at locations indicated. Pneumatic output lines shall have pressure gages mounted near the control panel.

3.1.5 Valves

Provide valve with stems upright where possible but with stems not lower than horizontal. Provide positioners where indicated and where necessary to prevent overlap of heating and cooling where one controller operates more than one pneumatic device and to maintain the proper dead band between heating and cooling.

3.1.6 Damper Actuators

Provide damper actuators so that the damper sealing action is smooth and sufficient to maintain leakage at or below specified leakage rate. Multiple actuators operating a common damper shall be connected to a common drive shaft. Provide positioners where indicated and where necessary to prevent overlap of heating and cooling where one controller operates more than one pneumatic device and to maintain the proper dead band between heating and cooling.

3.1.7 Access Doors

Provide access doors in ductwork to service airflow monitoring devices, devices with averaging elements, and low-temperature protection thermostats (freezestats).

3.1.8 Tubing

- a. Provide control system so that pneumatic lines are not exposed to air temperatures below 25 degrees F. Install tubes and tube bundles exposed to view neatly in lines parallel to lines of the building. Route tubing between panels and actuators in mechanical and electrical spaces so that lines are easily traceable. Tubes shall be permanently tagged on both ends with an identifier

indicated on shop drawings. Install concealed tubing in finished areas, and install exposed tubing in unfinished areas such as mechanical equipment rooms.

- b. Pneumatic lines in mechanical and electrical spaces shall be plastic tubing or copper tubing. Install horizontal and vertical runs of plastic tubes or soft copper tubing in raceways dedicated to tubing. Dedicated raceways shall be supported every 6 feet of horizontal run and every 8 feet for vertical runs. Tubing not installed in raceways shall be hard-drawn copper tubing with sweat fittings and valves, supported every 6 feet of horizontal run and every 8 feet for vertical runs.
- c. Tubing for connecting sensing elements and transmitters to liquid and steam lines shall be copper with brass compression fittings.
- d. Tubing for final connection of sensing elements and transmitters to ductwork shall be plastic with a maximum length of 12 inches.
- e. Tubing external to mechanical and electrical spaces, where run in plenum ceilings, shall be soft copper with sweat fittings, supported every 8 feet. Tubing not in plenum spaces shall be soft copper with sweat fittings supported every 8 feet or shall be plastic tubing in raceways dedicated to tubing.
- f. Provide tubing in concrete in rigid conduit. Install tubing in walls containing insulation, fill, or other packing materials in raceways dedicated to tubing.
- g. Final connections to actuators shall be plastic tubing, a maximum of 12 inches long and unsupported at the actuator.
- h. Provide a manual valve at each HVAC control panel to allow shutoff of main air. Pneumatic connections to HVAC control panels shall be made using bulkhead fittings except where bundled tubing is being used.
- i. Final connections to HVAC control panel bulkhead fittings shall be exposed tubing approximately 12 inches long.
- j. Tubing and two insulated copper phone wires for installation checkout may be run in the same conduit. Tubing and electrical power conductors shall not be run in the same conduit. Control circuit conductors, 24 V or less, may be run in the same conduit as polyethylene tubing.

3.1.9 Wiring

- a. Provide wiring external to control panels, including low-voltage wiring, in metallic raceways. Install wiring without splices between sensors, transmitters, control devices, and HVAC control panels. Install instrumentation grounding as necessary to prevent ground loops, noise, and surges adversely affecting operation of the system. Tag cables, conductors, and wires at both ends, with identifiers indicated on shop drawings.
- b. Other electrical work shall be specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide step-down transformers where control equipment operates at lower than line circuit

voltages. Transformers serving individual heating, ventilating, and air-conditioning units shall be fed from fan motor leads, or fed from the nearest distribution panelboard or motor control center, using circuits provided for that purpose.

- c. Ground control panels and cabinets as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Grounding of the green ac ground wire at the breaker panel alone is not adequate. Install ground wire from each control panel to adequate building ground.

3.1.10 Foundations and Housekeeping Pads

Provide 3 inch high concrete foundations and housekeeping pads for the HVAC control system air compressors.

3.1.11 Compressed Air Stations

Mount air compressor assembly on vibration eliminators, in accordance with ASME BPVC for tank clearance. Connect air line to the tank with a flexible pipe connector. Install compressed air station specialties with required tubing, including condensate tubing to a floor drain.

3.1.12 Control Drawings

Post laminated copies of as-built control system drawings in each mechanical room.

3.2 ADJUSTMENTS

Calibrate instrumentation and controls, and verify specified accuracy using test equipment traceable to National Institute for Science and Technology (NIST) standards. Adjust controls and equipment to maintain conditions indicated, to perform the functions indicated, and to operate in the sequence specified.

3.3 FIELD QUALITY CONTROL

- a. Demonstrate compliance of HVAC control systems. Furnish personnel, equipment, instrumentation, and supplies necessary to perform calibration and site testing. Calibrate test equipment in accordance with NIST standards. Ensure that tests are performed or supervised by competent employees of the control system installer or the control system manufacturer regularly employed in testing and calibration of control systems.
- b. Testing shall include field tests and the performance verification test. Field tests shall demonstrate proper calibration of instrumentation, input and output devices, and operation of specific equipment. The performance verification test shall ensure proper execution of sequence of operation and proper tuning of control loops.
- c. The plan for each phase of field acceptance testing shall be approved in writing before beginning that phase of testing. Furnish written notification of planned testing to Contracting Officer at least 21 days prior to testing. Include proposed test procedures with notification. The Contractor will not be allowed to start testing without written Government approval of test procedures. Test procedures shall consist of detailed

instructions for complete testing to prove the performance of heating, ventilating, and air-conditioning system and control system. Include the following tests in test procedures.

- d. Submit original copies of data produced, including results of each test procedure, to the Government at the conclusion of each phase of testing. Tests are subject to supervision and approval by Contracting Officer. Do not perform testing during scheduled seasonal off-periods of heating and cooling systems.

3.3.1 Test Reporting

After completion or termination of field tests and again after the performance verification test, identify, determine causes, replace, repair, or calibrate equipment which fails to meet the specification; and deliver a written report to the Government. The report shall document test results, explain in detail the nature of each failure, and corrective action taken. After delivering the performance verification test report, the Contractor shall convene a test review meeting at the job site to present results and recommendations to the Government. As a part of the test review meeting, the Contractor shall demonstrate by performing appropriate portions of field tests or the performance verification test that failures have been corrected. Based on Contractor's report and test review meeting, the Government will determine either the restart point or successful completion of testing. Do not commence required retesting until after receipt of written notification by the Government. At the conclusion of retesting, repeat the assessment.

3.3.2 Contractor's Field Testing

Calibrate field equipment and verify equipment and system operation before system is placed on-line. Include the following tests in field testing.

3.3.2.1 Tubing and Wiring Integrity Tests

Test tubing system pneumatically at 1.5 times the design working pressure for 24 hours. Allowable leakage rate is that which produces a pressure drop 1 psig in 24 hours with compressed air supply turned off. Test wiring for continuity, ground faults, and open and short circuits.

3.3.2.2 System Inspection

Observe HVAC control system in shutdown condition. Check dampers and valves for proper normal positions. Document positions for the performance verification test report.

3.3.2.3 Calibration Accuracy and Operation of Input Test

Verify correct calibration and operation of input instrument. For each sensor and transmitter, including for temperature, pressure, relative humidity, and dew point inputs, record the reading at the sensor or transmitter location using calibrated test equipment. Record the output reading provided by that sensor or transmitter. Document each of these location and output readings for the performance verification test report. The test equipment shall have been calibrated within one year of the date of use in the field. Test equipment calibration shall be traceable to the measurement standard of the National Institute of Standards and Technology.

3.3.2.4 Operation of Output Test

Check the operation of output to verify correct operation. Operate analog device to minimum range (e.g., 4 mA) and maximum range (e.g., 20 mA), and measure and record actual output values.

3.3.2.5 Actuator Range Adjustment

With the controller, apply a control signal to each actuator and verify that the actuator operates properly from its normal position through to the full range of stroke position. Record actual spring ranges and normal positions for modulating control valves and dampers.

3.3.3 Coordination With HVAC System Balancing

Tune the control system after air and hydronic systems have been balanced, minimum damper positions have been set, and a report has been issued.

3.3.4 Field Test Documentation

Before scheduling the performance verification test, provide field test documentation and written certification of completion to Contracting Officer and the Naval Energy and Environmental Support Activity (NEESA), that the installed system has been calibrated, tested, and is ready to begin the performance verification test. Do not start the performance verification test prior to receiving written permission from the Government.

3.3.5 Performance Verification Test

Conduct the performance verification tests to demonstrate that the control system maintains setpoints and that the control loops are tuned for the correct sequence of operation. Conduct the performance verification test during one week of continuous HVAC and control systems operation and before final acceptance of work. Specifically, the performance verification test shall demonstrate that the HVAC system operates properly through the complete sequence of operation (e.g., seasonal, occupied and unoccupied, warm up, etc.), for specified control sequences. Demonstrate proper control system response for abnormal conditions for which there is a specified system or controls response by simulating these conditions. Demonstrate that hardware interlocks and safety devices work as designed. Demonstrate that the control system performs the correct sequence of control.

3.3.6 Opposite Season Test

Repeat the performance verification test during an opposite season to the first performance verification test.

3.4 TRAINING

Provide a qualified instructor to conduct training courses for designated personnel in maintenance and operation of HVAC and control systems. Orientate training to the specific system being installed under the contract. Furnish audiovisual equipment and other training materials and supplies. A training day is defined as 8 hours of classroom or lab instruction, including two 15-minute breaks and excluding lunch time, Monday through Friday, during the daytime shift in effect at the training facility. For guidance, assume that the attendees have a high school

education and are familiar with HVAC systems. Submit planned training schedule, agenda, and class materials to the Government at least 45 days prior to training.

3.4.1 Training Course Documentation

Training shall be based on the operation and maintenance manuals and control system training manual. Deliver manuals for each trainee with two additional sets for archiving at the project site. Include an agenda, defined objectives, and a detailed description of subject matter for each lesson.

3.4.2 Operator Training I

The first class shall be taught for a period of 5 consecutive training days at least 1 month prior to the scheduled performance verification test. The first course shall be taught in a Government-provided facility on base. Training shall be classroom instruction, but have hands-on operation of similar digital controllers. Maximum of 5 personnel shall attend the course. Upon completion of course, each student, using appropriate documentation, shall be able to perform elementary operations, with guidance, and describe general hardware and functionality of the system. Course shall include but not be limited to description of hardware and operation of the system.

3.4.3 Operator Training II

The second course shall be taught in the field, using the operating equipment at project sites for a total of 16 hours of instruction per student, in blocks of 4 hours. Maximum of 5 personnel shall attend the course. Include hands-on training under constant monitoring of instructor. Course content shall duplicate the Operator Training I course as applied to the installed system. Instructor shall determine the level of the password to be issued to each student before each session. Upon completion of the course, students shall be proficient in system operation. Prepare a written report describing the skill level of each student at the end of the course.

3.4.4 Operator Training III

The third course shall be taught in the field, at the project site, for a period of 3 training days no later than 6 months after completion of endurance test. Maximum of 5 personnel shall attend the course. Course shall be structured to address specific topics that the students need to discuss and to answer questions concerning operation of the system. Upon completion of the course, students shall be proficient in system operation and shall have no unanswered questions regarding operation of the installed system.

3.4.5 System Maintenance Training

Course shall be taught at the project site within one month after completion of endurance test for a period of 2 training days. Maximum of personnel shall attend the course. Course shall include but not be limited to the following:

- a. Physical layout for each piece of hardware
- b. Troubleshooting and diagnostics procedures

- c. Repair instructions
- d. Preventive maintenance procedures and schedule
- e. Calibration procedures

3.5 QUALIFIED SERVICE ORGANIZATION LIST

The qualified service organization list shall include names and telephone numbers of organizations qualified to service HVAC control systems.

3.6 COMMISSIONING

Commissioning of control systems is specified in the pre-field TAB engineering report described in Section 23 05 93 TESTING, ADJUSTING AND BALANCING.

-- End of Section --

SECTION 23 09 93

SEQUENCES OF OPERATION FOR HVAC CONTROL
11/15

PART 1 GENERAL

1.1 DEFINITIONS

For definitions related to this Section, see Section 23 09 00
INTRUMENTATION AND CONTROL FOR HVAC.

1.2 SUBMITTALS

Submittals related to this Section are specified in Section 23 09 00
INTRUMENTATION AND CONTROL FOR HVAC.

PART 2 PRODUCTS

Products related to this Section are specified in Section 23 09 00
INTRUMENTATION AND CONTROL FOR HVAC and related Sections 23 09 13
INSTRUMENTATION AND CONTROL DEVICES FOR HVAC and 23 09 23.02 BACNET
DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

PART 3 EXECUTION

3.1 SEQUENCES OF OPERATION FOR OCCUPANCY SCHEDULING

3.1.1 System Mode

Operate air handling units (AHUs) in Occupied, Warm-Up-Cool-Down, or
Unoccupied modes as specified. VAV boxes, Fan Coils, and operate other
terminal equipment in Occupied or Unoccupied modes as specified.
Chillers, boilers, and other sources of heating/cooling for hydronic loads
do not require scheduling; these systems receive requests for
heating/cooling from their loads.

3.1.2 System Scheduler Requirements

The System Scheduler functionality must reside in either a piece of DDC
Hardware dedicated to this functionality or in the DDC Hardware
controlling the system AHU. A single piece of DDC Hardware dedicated to
scheduling (performing no other control functionality) may contain
multiple System Schedulers. Provide a unique System Scheduler for: each
AHU including it's associated Terminal Units, and each stand-alone
Terminal Unit (those not dependent upon AHU service) or group of
stand-alone Terminal Units acting according to a common schedule. Each
System Scheduler must provide the following functionality:

3.1.2.1 Scheduled Occupancy Input

Accept network variable of type SNVT_occupancy. Support the following
possible values: OC_STANDBY, OC_OCCUPIED and OC_UNOCCUPIED.

3.1.2.2 Occupancy Override Input

Accept network variable of type SNVT_occupancy. Support the following
possible values: OC_STANDBY, OC_OCCUPIED, OC_UNOCCUPIED, and OC_NUL.

3.1.2.3 Space Occupancy Inputs

For systems with multiple occupancy sensors, accept multiple inputs of network variable type SNVT_Occupancy. Support the following possible values: OC_OCCUPIED, OC_UNOCCUPIED, and OC_NUL. For systems with a single occupancy sensor, accept a network variable input of type SNVT_Occupancy or a hardware binary input (BI) indicating the space occupancy status as Occupied or Unoccupied.

3.1.2.4 Air Handler Occupancy Output

For a System Scheduler for a system containing an air handler, output one or more SNVTs indicating the desired occupancy status as one of the following possible values: Warm-Up-Cool-Down (when required by the AHU Sequence of Operation), Occupied and Unoccupied.

3.1.2.5 Terminal Unit Occupancy Output

For a System Scheduler for a stand-alone terminal unit, a group of stand-alone terminal units acting according to a common schedule, or a group of terminal units served by a single air handler, output one or more SNVTs indicating the desired occupancy status as one of the following possible values: Occupied and Unoccupied.

3.1.2.6 Default Schedule

Incorporate a 24-hour 7-day default schedule as shown on the drawings which may be activated and deactivated by the System Scheduler Logic.

3.1.2.7 Communication Determination

Determine the time elapsed between receipts of the scheduled occupancy input SNVT, and use this elapsed time to activate and deactivate the Default Schedule as specified. (This provides the capability for the system scheduler to use its Default Schedule if it loses communication with the UMCS).

3.1.3 System Scheduler Output Determination

For controlling an Air Handler, interpret a SNVT input of OC_STANDBY as Warm-Up-Cool-Down if the sequence of operation supports that mode, otherwise interpret OC_STANDBY as Occupied. For Terminal Units, interpret OC_STANDBY as Occupied.

3.1.3.1 Air Handler Occupancy Output

If more than 95 minutes have passed since the last receipt of the Scheduled Occupancy input, determine the Air Handler Occupancy Output by the default schedule and the Space Occupancy Inputs. Otherwise, determine the output as follows:

- a. If the Override Occupancy Input is not OC_NUL, determine the Air Handler Occupancy Output from the Override Occupancy Input.
- b. Otherwise, if at least the required number (as shown on the Occupancy Schedule Drawing) of Space Occupancy Inputs are OC_OCCUPIED or the hardware BI is Occupied the Air Handler Occupancy Output must be OC_OCCUPIED.

- c. Otherwise, determine the Air Handler Occupancy Output from the Scheduled Occupancy Input SNVT.

3.1.1.3.2 Terminal Unit Occupancy Output

If more than 95 minutes have passed since the last receipt of the Scheduled Occupancy input, determine the Terminal Unit Occupancy Output by the default schedule. Otherwise, determine the output as follows:

- a. If the Override Occupancy Input is not OC_NUL, determine the Terminal Unit Occupancy Output from the Override Occupancy Input SNVT:
- b. Otherwise, determine the Terminal Unit Occupancy Output from the Scheduled Occupancy SNVT.

3.1.1.4 Air Handler System Scheduling

- a. Bind the AHU Occupancy Output SNVT from the System Scheduler to the DDC Hardware that executes the Occupancy Mode Determination part of the Air Handler Sequence of Operation
- b. For Air Handlers using occupancy sensors, bind the output SNVT (of type SNVT_Occupancy) of each occupancy sensor to a Space Occupancy Input of the System Scheduler.
- c. Bind the Terminal Unit Occupancy Output SNVT from the System Scheduler to each AHU-Dependent Terminal Unit.
- d. AHU-Dependent Terminal Units with occupancy sensors must have the Effective Occupancy SNVT (of type SNVT_Occupancy) of each Terminal Unit bound to a Space Occupancy Input of the System Scheduler.

3.1.1.5 Stand-Alone Terminal Unit Scheduling

Bind the Terminal Unit Occupancy Output from the System Scheduler to the DDC Hardware that executes the Occupancy Mode Determination part of the Terminal Unit Sequence of Operation.

3.2 SEQUENCES OF OPERATION FOR AIR HANDLING UNITS

3.2.1 All-Air Small Package Unitary System

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control must be proportional-integral (PI) control.

3.2.1.1 Fan ON-AUTO Switch

3.2.1.1.1 ON

With the thermostat fan ON-AUTO switch in the ON position, the DDC Hardware must start and continuously run the fan.

3.2.1.1.2 AUTO

With the thermostat fan ON-AUTO switch in the AUTO position, the DDC Hardware operates the fan according to HEAT-OFF-COOL switch.

3.2.1.2 HEAT-OFF-COOL Switch

3.2.1.2.1 HEAT-COOL

With the thermostat switch in the HEAT or COOL positions, use the DDC Hardware to operate the package unit according to the Occupancy Mode.

3.2.1.2.2 OFF

With the thermostat switch in the OFF position, de-energize the heating unit and cooling unit with the DDC Hardware.

3.2.1.3 Occupancy Modes

3.2.1.3.1 Occupied

The unit DDC Hardware must be in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied or when the input from the System Scheduler is occupied.

3.2.1.3.2 Unoccupied

The unit DDC Hardware must be in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied and when the input from the System Scheduler is unoccupied.

3.2.1.4 Safeties

Run the unit subject to the unit manufacturer's safeties.

3.2.1.5 Zone Temperature Control

- a. In the Occupied Mode the zone temperature setpoint (ZN-T-SP) must be at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as indicated.
- b. In the Unoccupied Mode the zone temperature setpoint (ZN-T-SP-UNOCC) must be at the configured setpoint (ZN-T-SP-UNOCC) as indicated.
- c. Cycle the fan, cooling unit, heating unit with the DDC Hardware, in accordance with the HEAT-COOL switch setting, to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP).

3.2.2 Heating and Ventilating Unit (or Unit Ventilator)

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control must be proportional-integral (PI) control.

3.2.2.1 HAND-OFF-AUTO Switches

Provide supply fan motor starter to accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and starts the fan. Provide fan motor starter which accepts an occupant accessible emergency shutoff switch as indicated. Provide supply fan motor starter with an H-O-A switch:

3.2.2.1.1 HAND

With the H-O-A switch in HAND position, the supply fan starts and runs continuously, subject to Safeties.

3.2.2.1.2 OFF

With the H-O-A switch in OFF position, the supply fan stops.

3.2.2.1.3 AUTO

With the H-O-A switch in AUTO position, the supply fan runs subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.2.2 Occupancy Modes

Obtain the system's Occupancy Mode input from the System Scheduler as specified and indicated. Operate the system in one of the following modes:

3.2.2.2.1 Occupied

The Unit's DDC Hardware must be in the Occupied Mode when the input from the System Scheduler (SYS-OCC) is occupied or when the local space occupancy input(s) (ZN-OCC) indicate that the space is occupied.

3.2.2.2.2 Unoccupied

The Unit's DDC Hardware must be in the Unoccupied Mode when the input from the System Scheduler (SYS-OCC) is unoccupied and when the local space occupancy input(s) (ZN-OCC) indicate that the space is unoccupied.

3.2.2.3 System Enable and Loop Enable

3.2.2.3.1 Occupied Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS). Enable the Zone Temperature Control loop and Mixed Air Damper Control.

3.2.2.3.2 Unoccupied Mode

Disable all control loops. When BLDG-T drops below BLDG-T-LL-SP (with a 5 degrees F deadband) enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable the Zone Temperature Control loop.

3.2.2.4 Proofs and Safeties

Subject the supply fan and all DDC Hardware control loops to Proofs and Safeties. Direct-hardwire interlock safeties to the fan starter circuit as indicated. DDC Hardware must monitor all proofs and safeties and failure of any proof or activation of any safety must result in all control loops being disabled and the AHU fan being commanded off until reset.

3.2.2.4.1 Proofs

Supply fan status (proof) (SF-S)

3.2.2.4.2 Safeties

- a. Heating Coil discharge air temperature low limit (freeze stat)
(HTG-DA-T-LL)
- b. Supply air smoke (SA-SMK)
- c. Return air smoke (RA-SMK)

3.2.2.4.3 DDC Hardware

DDC Hardware reset all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as indicated on the Points Schedule drawing.

3.2.2.5 Zone Temperature Control

3.2.2.5.1 Enabled Loop

When this loop is enabled, the DDC Hardware must modulate the heating valve and outside air, relief, and return air dampers in sequence to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP). Provide sequencing as indicated: Upon a rise in zone temperature above zone temperature setpoint (ZN-T-SP), subject to the zone temperature setpoint deadband as indicated, modulate the outside air, relief, and return air dampers to maintain zone temperature at setpoint. During occupied mode, ensure outside air damper minimum position (OA-D-MIN) is as indicated. Upon a fall in zone temperature below zone temperature setpoint, subject to the deadband as indicated, modulate the heating valve towards open to maintain zone temperature setpoint.

3.2.2.5.2 Disabled Loop

When this loop is disabled, close the heating valve and close the outside air damper and relief damper and open the return damper.

3.2.2.6 Mixed Air Damper Control

When this is enabled, open the outside air and relief air dampers and close the return air damper. When this is disabled, close the outside air and relief air dampers and open the return air damper.

3.2.3 Single Zone with Heating and DXCooling Coils

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control must be proportional-integral (PI) control.

3.2.3.1 HAND-OFF-AUTO Switch

Provide supply fan motor starter to accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and starts the fan. Provide fan motor starter which accepts an occupant accessible emergency shutoff switch as indicated. Provide supply fan motor starter with an H-O-A switch:

3.2.3.1.1 HAND

With the H-O-A switch in HAND position, the supply fan starts and runs continuously, subject to Safeties.

3.2.3.1.2 OFF

With the H-O-A switch in OFF position, the supply fan stops.

3.2.3.1.3 AUTO

With the H-O-A switch in AUTO position, the supply fan runs subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.3.2 Occupancy Modes

Obtain the system's Occupancy Mode input from the System Scheduler as specified and indicated. Operate the system in one of the following modes: Occupied, Unoccupied.

3.2.3.3 System Enable and Loop Enable

3.2.3.3.1 Occupied Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable all control loops.

3.2.3.3.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL) disable all control loops and the supply fan does not run. When BLDG-T drops below BLDG-T-LL (with a 5 degrees F deadband) enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable the Heating Coil Temperature Control loop. Disable the Outside Air Flow Control, Economizer Damper Control, and DX Cooling Coil Control loops.

3.2.3.4 Proofs and Safeties

The supply fan and all DDC Hardware control loops are subject to Proofs and Safeties. Safeties must be direct-hardwire interlocked to the fan starter circuit as indicated. DDC Hardware must monitor all proofs and safeties and failure of any proof or activation of any safety result in all control loops being disabled and the AHU fan being commanded off until reset.

3.2.3.4.1 Proofs

Supply fan status (proof) (SF-S)

3.2.3.4.2 Safeties

- a. Heating coil discharge air temperature low limit (freeze stat) (HTG-DA-T-LL)
- b. Supply air smoke (SA-SMK)
- c. Return air smoke (RA-SMK)

3.2.3.4.3 DDC Hardware

Provide DDC Hardware reset of all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

3.2.3.5 Minimum Outside Air Flow Control

When this loop is enabled, open the 2-position minimum outside air damper to introduce the minimum outside air flow quantity as shown. When this loop is disabled, the minimum outside air damper will be closed.

3.2.3.6 Economizer Damper Control

3.2.3.6.1 Enabled Loop

When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, the DDC Hardware will modulate the economizer outside air, relief, and return air dampers (Economizer dampers) in sequence with the DX cooling coil control and heating coil control valve as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown.

3.2.3.6.2 Disabled Loop

When this loop is disabled, or the Economizer is OFF as determined by the Economizer Enable Logic, the economizer outside air and relief air dampers will be closed, and the return air damper will be open.

3.2.3.6.3 Economizer Enable Logic

Ensure the economizer is ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. Otherwise the Economizer is OFF. Ensure ECO-HL-SP and ECO-LL-SP each have a 2 degrees F deadband.

3.2.3.7 Heating Coil Control

When this loop is enabled, modulate the heating coil control valve in sequence with the DX staging control and economizer dampers as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown. When this loop is disabled, the heating coil control valve is closed.

3.2.3.8 DX Cooling Coil Control

When this loop is enabled the DDC Hardware must stage the DX Unit in sequence with the heating coil valve and economizer dampers as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown. When this loop is disabled, the DX unit is off .

3.2.4 Single Zone with Dual-Temperature Coil

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control must be proportional-integral (PI) control.

3.2.4.1 HAND-OFF-AUTO Switch

Provide supply fan motor starter to accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and starts the fan. Provide fan motor starter which accepts an occupant accessible emergency shutoff switch as indicated. Provide supply fan motor starter with an H-O-A switch:

3.2.4.1.1 HAND

With the H-O-A switch in HAND position, the supply fan starts and runs continuously, subject to Safeties.

3.2.4.1.2 OFF

With the H-O-A switch in OFF position, the supply fan stops.

3.2.4.1.3 AUTO

With the H-O-A switch in AUTO position, the supply fan runs subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.4.2 Occupancy Modes

Obtain Occupancy Mode input from the System Scheduler as specified and shown. Operate the system in one of the following modes: Occupied, Unoccupied.

3.2.4.3 System Enable and Loop Enable

3.2.4.3.1 Occupied Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable all control loops.

3.2.4.3.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the building low limit setpoint (BLDG-T-LL), disable all control loops and do not run the supply fan. When BLDG-T drops below BLDG-T-LL (with a 5 degrees F deadband), enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable the Dual Temperature Coil Temperature Control loop. Disable the Minimum Outside Air Flow Control and Economizer Damper Control loops.

3.2.4.4 Proofs and Safeties

The supply fan and all DDC Hardware control loops are subject to Proofs and Safeties. Direct-hardwire interlock safeties to the fan starter circuit as shown. Monitor all proofs and safeties, and disable all control loops and command the AHU fan off until reset due to failure of any proof or activation of any safety.

3.2.4.4.1 Proofs

Supply fan status (proof) (SF-S)

3.2.4.4.2 Safeties

a. Dual Temperature coil discharge air temperature low limit (freeze

stat) (DT-DA-T-LL)

b. Supply air smoke (SA-SMK)

c. Return air smoke (RA-SMK)

3.2.4.4.3 DDC Hardware

Reset all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

3.2.4.5 Minimum Outside Air Flow Control

When this loop is enabled, open the 2-position minimum outside air damper to introduce the minimum outside air flow quantity as shown. When this loop is disabled, close the minimum outside air damper.

3.2.4.6 Economizer Damper Control

3.2.4.6.1 Enabled Loop

When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, modulate the economizer outside air, relief, and return air dampers (Economizer dampers) in sequence with the dual temperature coil to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown.

3.2.4.6.2 Disabled Loop

When this loop is disabled, or the Economizer is OFF as determined by the Economizer Enable Logic, close the economizer outside air and relief air dampers, and open the return air damper.

3.2.4.6.3 Economizer Enable Logic

Ensure the economizer is ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. Otherwise the Economizer is OFF. Ensure ECO-HL-SP and ECO-LL-SP each have a 2 degrees F deadband.

3.2.4.7 Dual Temperature Coil Control

3.2.4.7.1 Enabled Loop

When this loop is enabled, select heating or cooling mode based on a pipe-mounted dual-temperature supply water sensor. A single sensor may be used for multiple instances of this sequence.

3.2.4.7.2 DDC Hardware

Modulate the coil control valve in sequence with the economizer dampers as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown.

3.2.4.7.3 Disabled Loop

When this loop is disabled, close the control valve.

3.2.5 Single Zone with Heating and Cooling Coils and Return Air Bypass

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control are proportional-integral (PI) control.

3.2.5.1 HAND-OFF-AUTO Switch

Provide supply fan motor starter to accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and starts the fan. Provide fan motor starter which accepts an occupant accessible emergency shutoff switch as indicated. Provide supply fan motor starter with an H-O-A switch:

3.2.5.1.1 HAND

With the H-O-A switch in HAND position, start the supply fan and run continuously, subject to Safeties.

3.2.5.1.2 OFF

With the H-O-A switch in OFF position, stop the supply fan.

3.2.5.1.3 AUTO

With the H-O-A switch in AUTO position, run the supply fan subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.5.2 Occupancy Modes

Obtain the Occupancy Mode input from the System Scheduler as specified and shown. Operate the system in one of the following modes: Occupied, Unoccupied.

3.2.5.3 System Enable and Loop Enable

3.2.5.3.1 Occupied Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable all control loops.

3.2.5.3.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL) disable all control loops and do not run the supply fan. When BLDG-T drops below BLDG-T-LL (with a 5 degrees F deadband), enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable the Heating Coil Temperature Control loop. Disable all other control loops.

3.2.5.4 Proofs and Safeties

The supply fan and all DDC Hardware control loops are subject to Proofs and Safeties. Direct-hardwire interlock safeties to the fan starter circuit as shown. Monitor all proofs and safeties and disable all control loops and command the AHU fan off until reset due to failure of any proof or activation of any safety.

3.2.5.4.1 Proofs

Supply fan status (proof) (SF-S)

3.2.5.4.2 Safeties

- a. Heating coil discharge air temperature low limit (freezestat)
(HTG-DA-T-LL)
- b. Supply air smoke (SA-SMK)
- c. Return air smoke (RA-SMK)

3.2.5.4.3 DDC Hardware

Reset all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

3.2.5.5 Minimum Outside Air Flow Control

When this loop is enabled the DDC Hardware, open the 2-position minimum outside air damper to introduce the minimum outside air flow quantity as shown. When this loop is disabled, close the minimum outside air damper.

3.2.5.6 Economizer Damper Control

3.2.5.6.1 Enabled Loop

When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, modulate the economizer outside air, return air, and relief air dampers (Economizer dampers) in sequence with the bypass and supply dampers and the heating coil control valve as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown.

3.2.5.6.2 Disabled Loop

When this loop is disabled, or the Economizer is OFF as determined by the Economizer Enable Logic, close the economizer outside air and relief air dampers, and open the return air damper.

3.2.5.6.3 Economizer Enable Logic

Ensure the economizer is ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. Otherwise the Economizer is OFF. Ensure ECO-HL-SP and ECO-LL-SP each have a 2 degrees F deadband.

3.2.5.7 Temperature Control Loop Heating Coil Control

When this loop is enabled, modulate the heating coil control valve, modulate the economizer dampers if enabled, open and close the 2-position cooling coil valve and modulate the bypass and supply air dampers in sequence to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown. When this loop is disabled, close both valves and position the bypass and supply air dampers to bypass air.

3.2.6 Single Zone with Humidity Control

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control are proportional-integral (PI) control.

3.2.6.1 HAND-OFF-AUTO Switch

Provide supply fan motor starter to accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and starts the fan. Provide fan motor starter which accepts an occupant accessible emergency shutoff switch as indicated. Provide supply fan motor starter with an H-O-A switch:

3.2.6.1.1 HAND

With the H-O-A switch in HAND position, start the supply fan and run continuously, subject to Safeties.

3.2.6.1.2 OFF

With the H-O-A switch in OFF position, stop the supply fan.

3.2.6.1.3 AUTO

With the H-O-A switch in AUTO position, run the supply fan subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.6.2 Occupancy Modes

Obtain Occupancy Mode input from the System Scheduler as specified and shown. Operate the system in one of the following modes: Occupied, Unoccupied.

3.2.6.3 System Enable and Loop Enable

3.2.6.3.1 Occupied Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable all control loops.

3.2.6.3.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL), disable all control loops and do not run the supply fan. When BLDG-T drops below BLDG-T-LL (with a 5 degrees F deadband), enable the supply fan (SYS-ENA) and command to run (SF-SS), enable the Preheat Coil Control loop and Reheat Coil Control loop and disable all other loops.

3.2.6.4 Proofs and Safeties

The supply fan and all DDC Hardware control loops are subject to Proofs and Safeties. Direct-hardwire interlock safeties to the fan starter circuit as shown. Monitor all proofs and safeties and disable all control loops and command the AHU fan off until reset due to failure of any proof or activation of any safety.

3.2.6.4.1 Proofs

Supply fan status (proof) (SF-S)

3.2.6.4.2 Safeties

- a. Preheat coil discharge air temperature low limit (freezestat) (PH-DA-T-LL)
- b. Supply air smoke (SA-SMK)
- c. Return air smoke (RA-SMK)

3.2.6.4.3 DDC Hardware

Reset all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where both reset functions are provided and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

3.2.6.5 Minimum Outside Air Flow Control

When this loop is enabled, open the 2-position minimum outside air damper to introduce the minimum outside air flow quantity as shown. When this loop is disabled, close the minimum outside air damper.

3.2.6.6 Preheat Coil Control Loop

When this loop is enabled, modulate the preheat coil valve to maintain the preheat coil discharge air temperature (PH-DA-T) at setpoint (PH-DA-T-SP) as shown. When this loop is disabled, close the preheat coil valve.

3.2.6.7 Cooling-and-Dehumidification Coil Control

When this loop is enabled, modulate the cooling and dehumidification valve to maintain either the zone temperature (ZN-T) at setpoint (ZN-T-SP) or zone relative humidity (ZN-RH) at setpoint (ZN-RH-SP), whichever calls for more chilled water flow. Modulate the valve in sequence with the reheat valve and humidification valve as shown to avoid simultaneous cooling and reheating, and simultaneous dehumidification and humidification. When this loop is disabled, close the coil valve.

3.2.6.8 Reheat Coil Control

When this loop is enabled, modulate the reheat coil valve to maintain the zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown. Modulate the valve in sequence with the cooling-and-dehumidification valve as shown to avoid simultaneous cooling and reheating. When this loop is disabled, close the coil valve.

3.2.6.9 Humidification Control

When this loop is enabled, modulate the humidifier valve to maintain zone relative humidity (ZN-RH) at setpoint (ZN-RH-SP). Modulate the valve in sequence with the cooling-and-dehumidification valve as shown to avoid simultaneous dehumidification and humidification. When the supply air duct humidity (SA-RH) rises above 80 percent relative humidity, begin modulating the humidifier valve towards closed and continue to gradually

move towards closed until the supply air duct humidity reaches 90 percent relative humidity, at which point the humidifier valve is fully closed. When this loop is disabled, close the humidifier valve.

3.2.7 Multizone without Return Fan

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control are proportional-integral (PI) control.

3.2.7.1 HAND-OFF-AUTO switches and Fire Alarm Panel (FAP) Signal:

Supply Fan VFD. Provide supply fan motor starter to accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and starts the fan. Provide fan motor starter which accepts an occupant accessible emergency shutoff switch as shown. Provide supply fan motor starter with an H-O-A switch:

3.2.7.1.1 HAND

With the H-O-A switch in HAND position, the supply fan starts and runs continuously, subject to Safeties.

3.2.7.1.2 OFF

With the H-O-A switch in OFF position, the supply fan stops.

3.2.7.1.3 AUTO

With the H-O-A switch in AUTO position, the supply fan runs subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.7.2 Occupancy Modes

Obtain Occupancy Mode input from the System Scheduler as specified and shown. Operate the system in one of the following modes: Occupied, Unoccupied.

3.2.7.3 System Enable and Loop Enable

3.2.7.3.1 Occupied Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS). Enable all control loops. Also enable the Zone Temperature Control loops serviced by the AHU.

3.2.7.3.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL), disable all control loops and do not run the supply fan. When BLDG-T drops below BLDG-T-LL (with a 5 degrees F deadband), enable the supply fan (SYS-ENA) and command to run (SF-SS), enable the Hot Deck Coil Control loop and all Zone Temperature Control loops, and disable all other control loops.

3.2.7.4 Proofs and Safeties

The supply fan and all DDC Hardware control loops are subject to Proofs

and Safeties. Direct-hardwire interlock safeties to the fan starter circuit as shown. Monitor all proofs and safeties and disable all control loops and command the AHU fan off until reset due to failure of any proof or activation of any safety.

3.2.7.4.1 Proofs

- a. Supply fan status (proof) (SF-S)

3.2.7.4.2 Safeties

- a. Mixed air temperature low limit (freeze stat) (MA-T-LL)
- c. Return air smoke (RA-SMK)

3.2.7.4.3 DDC Hardware Reset

Reset all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

3.2.7.5 Minimum Outside Air Flow Control

When this loop is enabled, open the 2-position minimum outside air damper to introduce the minimum outside air follow quantity as shown. When this loop is disabled, close the minimum outside air damper.

3.2.7.6 Mixed Air Temperature Control With Economizer

3.2.7.6.1 Enabled Loop

When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, modulate the economizer outside air, relief, and return air dampers to maintain the mixed air temperature (MA-T) at setpoint (MA-T-SP) as shown.

3.2.7.6.2 Disabled Loop

When this loop is disabled, or the Economizer is OFF as determined by the Economizer Enable Logic, close the economizer outside air and relief air dampers, and open the return air damper.

3.2.7.6.3 Economizer Enable Logic

Ensure the economizer is ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. Otherwise the Economizer is OFF. Ensure ECO-HL-SP and ECO-LL-SP each have a 2 degrees F deadband.

3.2.7.7 Hot Deck Coil Control

3.2.7.7.1 Enabled Loop

When this loop is enabled, modulate the hot deck heating coil valve to maintain the hot deck temperature (HD-T) at setpoint (HD-T-SP) as shown. When this loop is disabled, close the hot deck coil valve.

3.2.7.7.2 DDC Hardware Reset

Reset the hot deck temperature setpoint (HD-T-SP) using a linear reset schedule as shown. Base reset of the setpoint (HD-T-SP) on Outside Air Temperature .

3.2.7.8 Cold Deck Coil Control

When this loop is enabled, modulate the cold deck cooling coil valve to maintain the cold deck temperature (CD-T) at setpoint (CD-T-SP) as shown. When this loop is disabled, close the cold deck cooling coil valve.

3.2.7.9 Zone Temperature Control

When this loop is enabled:

3.2.7.9.1 Zone Temperature Setpoint

Ensure zone temperature setpoint (ZN-T-SP) is at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.

3.2.7.9.2 DDC Hardware Modulation

Modulate the hot deck and cold deck dampers to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP).

3.2.8 Variable Air Volume System without Return Fan

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.2.8.1 HAND-OFF-AUTO Switches

Provide supply fan variable frequency drive (VFD) unit to accept a Fire Alarm Panel (FAP) signal that takes precedence over all other VFD inputs and switches and causes the VFD to run at 100 percent speed. Provide VFD that accepts an occupant accessible emergency shutoff switch as shown. Provide supply fan variable frequency drive (VFD) unit with an integral H-O-A switch:

3.2.8.1.1 HAND

With the H-O-A switch in HAND position, start the supply fan and run continuously, subject to Safeties. Ensure fan speed is under manual-operator control.

3.2.8.1.2 OFF

With the H-O-A switch in OFF position, stop the supply fan.

3.2.8.1.3 AUTO

With the H-O-A switch in AUTO position, run the supply fan subject to the Supply Fan Start/Stop Signal (SF-SS) and Safeties. Ensure fan speed is under control of the DDC Hardware.

3.2.8.2 Occupancy Modes

Obtain Occupancy Mode input from the System Scheduler as specified and shown. Operate the system in one of the following modes: Occupied, Unoccupied.

3.2.8.3 Proofs and Safeties

The supply fan and all DDC Hardware control loops are subject to Proofs and Safeties. Direct-hardwire interlock safeties to the VFD as shown. Monitor all proofs and safeties and disable all control loops and command the AHU fan off until reset due to failure of any proof or activation of any safety.

3.2.8.3.1 Proofs

- a. Supply fan status (SF-S)

3.2.8.3.2 Safeties

- a. Preheat coil discharge air temperature low limit (freezestat) (PH-DA-T-LL) for systems with a preheat coil. Cooling coil discharge air temperature low limit (freezestat) (CLG-DA-T-LL) for all other systems
- b. Supply air duct pressure high limit (SA-P-HL)
- c. Supply air smoke (SA-SMK)
- d. Return air smoke (RA-SMK)

3.2.8.3.3 DDC Hardware Reset

Reset all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

3.2.8.4 System Enable and Loop Enable

3.2.8.4.1 Occupied Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS). Enable all control loops.

3.2.8.4.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL) disable all control loops and do not run the supply fan. When BLDG-T drops below BLDG-T-LL (with a 5 degrees F deadband), enable the supply fan (SYS-ENA) and command to run (SF-SS), enable the Supply Duct Static Pressure Control loops. Disable the Minimum Outside Air Flow Control, Mixed Air Temperature Control, and Cooling Coil Control loops.

3.2.8.5 Fan Capacity Control

3.2.8.5.1 Supply Duct Static Pressure Control

When this loop is enabled, modulate the supply fan variable frequency drive unit to maintain the duct static pressure (SA-P) at setpoint (SA-P-SP) as shown, as measured by the duct static pressure tap and sensor as shown. When this loop is disabled, ensure the DDC Hardware capacity modulation output to the VFD is zero percent.

3.2.8.6 Minimum Outside Air Flow Control

When this loop is enabled, modulate the minimum outside air damper to maintain the minimum OA volumetric flow (MINOA-F) at setpoint (MINOA-F-SP) as shown. When this loop is disabled, close the minimum outside air damper.

3.2.8.7 Mixed Air Temperature Control With Economizer

3.2.8.7.1 Enabled Loop

When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, modulate the economizer outside air, relief, and return air dampers to maintain the mixed air temperature (MA-T) at setpoint (MA-T-SP) as shown.

3.2.8.7.2 Disabled Loop

When this loop is disabled, or the Economizer is OFF as determined by the Economizer Enable Logic, close the economizer outside air and relief air dampers, and open the return air damper.

3.2.8.7.3 Economizer Enable Logic

Ensure the economizer is ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. Otherwise the Economizer is OFF. Ensure ECO-HL-SP and ECO-LL-SP each have a 2 degrees F deadband.

3.2.8.8 Cooling Coil Control

When this loop is enabled, modulate the cooling coil valve to maintain the supply air temperature (SA-T) setpoint (SA-T-SP) as shown. When this loop is disabled, close the cooling coil valve.

3.3 SEQUENCES OF OPERATION FOR TERMINAL UNITS

3.3.1 Zone Temperature Control - Cooling-Only VAV Box

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.3.1.1 Occupancy Modes

3.3.1.1.1 Occupied

Ensure the VAV box DDC Hardware is in the Occupied Mode when the local

space occupancy input(s) (ZN-OCC) indicate that the space is occupied or when the input from the System Scheduler (SYS-OCC) is occupied.

3.3.1.1.2 Unoccupied

The VAV box DDC Hardware must be in the Unoccupied Mode when the local space occupancy input(s) (ZN-OCC) indicate that the space is unoccupied and the input from the System Scheduler (SYS-OCC) is unoccupied.

Safeties

This system has no safeties.

3.3.1.2 Zone Temperature Control

3.3.1.2.1 Occupied Mode

In the Occupied Mode the zone temperature setpoint (ZN-T-SP) must be at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown. The DDC Hardware must modulate the VAV box damper to maintain VAV box supply air flow (VAV-SA-F) at setpoint as measured by a multi-point flow sensing element at the inlet to the VAV box. Sequence as indicated: Upon a rise in zone temperature (ZN-T) above zone setpoint (ZN-T-SP), subject to the zone temperature setpoint deadband as indicated, adjust the airflow setpoint between minimum and maximum flow based on the difference between zone temperature and zone temperature setpoint as indicated.

3.3.1.2.2 Unoccupied Mode

In the Unoccupied Mode, ensure the VAV box damper is at its minimum position.

3.3.2 Zone Temperature Control - VAV Box with Reheat

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.3.2.1 Occupancy Modes

3.3.2.1.1 Occupied

Ensure the VAV box DDC Hardware is in the Occupied Mode when the local space occupancy input(s) (ZN-OCC) indicate that the space is occupied or when the input from the System Scheduler (SYS-OCC) is occupied.

3.3.2.1.2 Unoccupied

Ensure the VAV box DDC Hardware is in the Unoccupied Mode when the local space occupancy input(s) (ZN-OCC) indicate that the space is unoccupied and the input from the System Scheduler (SYS-OCC) is unoccupied.

3.3.2.2 Safeties

For VAV boxes with electric resistance heating elements, require proof of air flow before activating the heating elements.

3.3.2.3 Zone Temperature Control

- a. In the Occupied Mode, ensure the zone temperature setpoint (ZN-T-SP) is at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.
- b. In the Unoccupied Mode, ensure the zone temperature setpoint (ZN-T-SP) is at the configured setpoint as shown.
- c. Modulate the VAV box damper to maintain VAV box supply air flow (VAV-SA-F) at setpoint as measured by a multi-point flow sensing element at the inlet to the VAV box. Perform sequencing as shown: Upon a rise in zone temperature above zone temperature setpoint (ZN-T-SP), subject to the zone temperature setpoint deadband as shown, adjust the airflow setpoint between minimum and maximum flow based on the difference between zone temperature and zone temperature setpoint as shown. Upon a fall in zone temperature below zone temperature setpoint, subject to the deadband as shown, maintain the airflow at a fixed air flow setpoint (with a setting independent of the cooling minimum air flow), and modulate the heating valve towards open or cycle the staged electric resistance heating coil(s) on in sequence.

3.3.3 Zone Temperature Control - Fan Powered VAV Box

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.3.3.1 Occupancy Modes

3.3.3.1.1 Occupied

Ensure the VAV box DDC Hardware is in the Occupied Mode when the local space occupancy input(s) (ZN-OCC) indicate that the space is occupied or when the input from the System Scheduler (SYS-OCC) is occupied.

3.3.3.1.2 Unoccupied

Ensure the VAV box DDC Hardware is in the Unoccupied Mode when the local space occupancy input(s) (ZN-OCC) indicate that the space is unoccupied and the input from the System Scheduler (SYS-OCC) is unoccupied.

3.3.3.2 Safeties

For VAV boxes with electric resistance heating elements, require proof of air flow before activating the heating elements.

3.3.3.3 Fan Control

3.3.3.4 Zone Temperature Control

3.3.3.4.1 Occupied Mode

In the Occupied Mode, ensure the zone temperature setpoint (ZN-T-SP) is at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.

3.3.3.4.2 Unoccupied Mode

In the Unoccupied Mode, ensure the zone temperature setpoint (ZN-T-SP) is at the configured setpoint as shown.

3.3.3.4.3 Sequencing

3.3.3.4.3.1 Cooling Mode

Upon a rise in zone temperature above zone temperature setpoint (ZN-T-SP), subject to the zone temperature setpoint deadband as shown, adjust the airflow setpoint between minimum and maximum based on the difference between zone temperature and zone temperature setpoint as shown. Modulate the VAV box damper to mix supply and plenum return air as it maintains VAV box supply airflow (VAV-SA-F) at setpoint as measured by a multi-point flow sensing element at the inlet to the VAV box.

3.3.3.4.3.2 Heating Mode

Upon a fall in zone temperature below zone temperature setpoint, subject to the deadband as shown, the DDC Hardware must modulate the VAV box damper to mix supply and plenum return air to maintain a fixed air flow setpoint (with a setting independent of the cooling minimum air flow), and modulate the heating valve towards open or cycle the staged electric resistance heating coil(s) on in sequence.

3.3.4 Perimeter Radiation Control Sequence

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.3.4.1 Occupancy Modes

3.3.4.1.1 Occupied

Ensure the radiator DDC Hardware is in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied or when the input from the System Scheduler is occupied.

3.3.4.1.2 Unoccupied

Ensure the radiator DDC Hardware is in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied and when the input from the System Scheduler is unoccupied.

3.3.4.2 Safeties

This system has no safeties.

3.3.4.3 Space Temperature Control

3.3.4.3.1 Occupied Mode

In the Occupied Mode, modulate the heating control valve to maintain space temperature at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.

3.3.4.3.2 Unoccupied Mode

In the Unoccupied Mode, modulate the heating control valve to maintain space temperature at the configured setpoint as shown.

3.3.5 Unit Heater and Cabinet Unit Heater

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.3.5.1 Off-Auto Switch

3.3.5.1.1 OFF

With the thermostat OFF-AUTO switch in the OFF position, stop the fan and close the heating control valve.

3.3.5.1.2 AUTO

With the thermostat OFF-AUTO switch in the AUTO position, control the unit in accordance with its Occupancy Mode.

3.3.5.2 Occupancy Modes

3.3.5.2.1 Occupied

Ensure the unit heater DDC Hardware is in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied or when the input from the System Scheduler is occupied.

3.3.5.2.2 Unoccupied

Ensure the unit heater DDC Hardware is in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied and when the input from the System Scheduler is unoccupied.

3.3.5.3 Safeties

Run the unit subject to the unit manufacturer's safeties.

3.3.5.4 Space Temperature Control

3.3.5.4.1 Occupied Mode

In the Occupied Mode, modulate the heating control valve and cycle the multi-speed fan to maintain space temperature at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.

3.3.5.4.2 Unoccupied Mode

In the Unoccupied Mode, modulate the heating control valve and cycle the multi-speed fan to maintain space temperature at the configured setpoint as shown.

3.3.6 Gas-Fired Infrared Heater

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.3.6.1 On-Off-Auto Switch

3.3.6.1.1 ON

With the thermostat ON-OFF-AUTO switch in the ON position, energize the heater and run the heater continuously.

3.3.6.1.2 OFF

With the thermostat ON-OFF-AUTO switch in the OFF position, de-energize the heater.

3.3.6.1.3 AUTO

With the thermostat ON-OFF-AUTO switch in the AUTO position, control the heater in accordance with its Occupancy Mode.

3.3.6.2 Occupancy Modes

3.3.6.2.1 Occupied

Ensure the unit DDC Hardware is in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied.

3.3.6.2.2 Unoccupied

Ensure the unit DDC Hardware is in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied.

3.3.6.3 Safeties

Run the heater subject to the unit manufacturer's safeties.

3.3.6.4 Space Temperature Control

3.3.6.4.1 Occupied Mode

In the Occupied Mode, operate the heater to maintain space temperature at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as indicated.

3.3.6.4.2 Unoccupied Mode

In the Unoccupied Mode, operate the heater to maintain space setpoint at the configured unoccupied setpoint as indicated.

3.3.7 Dual Temperature Fan-Coil Unit

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.3.7.1 Off-Auto Switch

3.3.7.1.1 OFF

With the thermostat OFF-AUTO switch in the OFF position, stop the fan and close the dual-temperature control valve.

3.3.7.1.2 AUTO

With the thermostat OFF-AUTO switch in the AUTO position, control the unit in accordance with its Occupancy Mode.

3.3.7.2 Occupancy Modes

3.3.7.2.1 Occupied

Ensure the unit DDC Hardware is in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied or when the input from the System Scheduler is occupied.

3.3.7.2.2 Unoccupied

Ensure the unit DDC Hardware is in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied and when the input from the System Scheduler is unoccupied.

3.3.7.3 Heat/Cool Modes

Automatically switch the fan coil unit DDC Hardware between the heating and cooling modes and the resultant control action, based on a pipe-mounted dual-temperature supply water temperature sensor.

3.3.7.4 Safeties

Run the unit subject to the unit manufacturer's safeties.

3.3.7.5 Space Temperature Control

3.3.7.5.1 Occupied Mode

In the Occupied Mode, modulate the dual-temperature control valve and modulate the multi-speed fan to maintain space temperature at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as indicated.

3.3.7.5.2 Unoccupied Mode

In the Unoccupied Mode, modulate the dual-temperature control valve and modulate the multi-speed fan to maintain space temperature at the configured setpoint as indicated.

3.4 SEQUENCES OF OPERATION FOR HYDRONIC SYSTEMS

3.4.1 Hydronic Heating Hot Water from Distributed HTHW Converter

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control must be

proportional-integral (PI) control.

3.4.1.1 System Enable and Loop Enable

- a. Monitor the enabled status of all systems served by this system. .
- b. When this system is enabled (SYS-ENA) command the hot water pump on via the Hot Water Pump Start/Stop (HW-PMP-SS) command.
- c. When this system is enabled (SYS-ENA) and the hot water pump is proofed on, enable the Heat Exchanger Control loop.

3.4.1.2 HAND-OFF-AUTO Switch

Provide hot water pump motor starter with an H-O-A switch:

3.4.1.2.1 HAND

With the H-O-A switch in HAND position, the pump starts and runs continuously.

3.4.1.2.2 OFF

With the H-O-A switch in OFF position, the pump stops.

3.4.1.2.3 AUTO

With the H-O-A switch in AUTO position, the pump runs subject to the Hot Water Pump Start/Stop (HW-PMP-SS) command.

3.4.1.3 Proofs and Safeties

DDC Hardware must monitor all proofs and safeties.

3.4.1.3.1 Proofs

Hot water pump status (HW-PMP-S)

3.4.1.3.2 Safeties

None

3.4.1.3.3 DDC Hardware Reset

Reset all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as indicated on the Points Schedule drawing.

3.4.1.4 Heat Exchanger Valve Control

When this loop is enabled modulate the high temperature hot water valve to maintain the Hot Water Supply Temperature (HWS-T) at setpoint (HWS-T-SP). The Hot Water Supply Temperature Setpoint (HW-T-SP) must be determined from a linear reset schedule as shown. When this loop is disabled, close the valve.

3.4.2 Hydronic Heating Hot Water From Single-Building Boiler

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.4.2.1 System Enable and Loop Enable

- a. Monitor the enabled status of all systems served by this system. If one or more systems served by this system are enabled, enable this system (SYS-ENA). If no systems served by this system are enabled, disable this system.
- b. When this system is enabled (SYS-ENA) and the hot water pump is proofed on, enable the boiler control and hot water temperature control loops.

3.4.2.2 HAND-OFF-AUTO Switch

Provide hot water pump motor starter with an H-O-A switch:

3.4.2.2.1 HAND

With the H-O-A switch in HAND position, start the pump and run continuously.

3.4.2.2.2 OFF

With the H-O-A switch in OFF position, stop the pump.

3.4.2.2.3 AUTO

With the H-O-A switch in AUTO position, run the pump subject to the Hot Water Pump Start/Stop (HW-PMP-SS) command.

3.4.2.3 Proofs and Safeties

DDC Hardware must monitor all proofs and safeties.

3.4.2.3.1 Proofs

Hot water pump

3.4.2.3.2 Safeties

None

3.4.2.3.3 DDC Hardware Reset

Reset all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

3.4.2.4 Boiler Control

When this loop is enabled, turn the boiler on. When this loop is

disabled, the boiler is turned off.

3.4.2.5 Hot Water Temperature Control

When this loop is enabled modulate the 3-way mixing valve to maintain hot water supply temperature (HWS-T) at setpoint (HWS-T-SP). The Hot Water Supply Temperature Setpoint (HWS-T-SP) must be determined from a linear reset schedule as shown. When this loop is disabled, the valve is in its normal (failsafe) position.

3.4.3 Hydronic Dual-Temperature System with High Temperature Hot Water Heat Exchanger and Chilled Water

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.4.3.1 System Enable and Loop Enable

- a. Monitor the enabled status of all systems served by this system. If one or more systems served by this system are enabled, enable this system (SYS-ENA). If all systems served by this system are not enabled, do not enable this system.
- b. When the system is enabled (SYS-ENA), run the pump.
- c. When this system is enabled (SYS-ENA), and the HEATING/COOLING switch is in HEATING the Heat Exchanger Control loop is enabled.

3.4.3.2 Switchover Valve Operation

Monitor the status of the DTWR-T-LL and DTWR-T-HL switches.

3.4.3.2.1 HEATING/COOLING Switch in the HEATING Position

With the HEATING/COOLING switch in the HEATING position, the switchover valve must open the heat-cool system piping to the heat exchanger and close the heat-cool system piping to the .

3.4.3.2.2 HEATING/COOLING Switch in the COOLING Position

With the HEATING/COOLING switch in the COOLING position, the switchover valve must open the heat-cool system piping to the and close the heat-cool system piping to the heat exchanger whenever the dual-temperature return water temperature (DTWR-T) is below the dual-temperature return water high-limit temperature (DTWR-T-HL).

3.4.3.3 HAND-OFF-AUTO Switch

Provide Dual-Temperature water pump motor starter with an H-O-A switch:

3.4.3.3.1 HAND

With the H-O-A switch in HAND position, the pump starts and runs continuously.

3.4.3.3.2 OFF

With the H-O-A switch in OFF position, the pump stops.

3.4.3.3.3 AUTO

With the H-O-A switch in AUTO position, the pump runs subject to the Dual-Temperature Water Pump Start/Stop (DTW-PMP-SS) System Enable (SYS-ENA) command.

3.4.3.4 Proofs and Safeties

DDC Hardware must monitor all proofs and safeties.

3.4.3.4.1 Proofs

None

3.4.3.4.2 Safeties

Direct-hardwire interlock heat exchanger differential pressure switch (HX-P-LL) to the high temperature hot water valve.

3.4.3.4.3 DDC Hardware Reset

Reset all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

3.4.4 Hydronic Secondary with Variable Speed Pump

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control is proportional-integral (PI) control.

3.4.4.1 System Enable and Loop Enable:

- a. Monitor the enabled status of all systems served by this system. If one or more systems served by this system are enabled, enable this system (SYS-ENA). If all systems served by this system are not enabled, do not enable this system.
- b. When this system is enabled (SYS-ENA) the Pressure Control loop must be enabled.

3.4.4.2 HAND-OFF-AUTO Switch

Provide hot water pump variable frequency drive (VFD) unit with an integral H-O-A switch:

3.4.4.2.1 HAND

With the H-O-A switch in HAND position, the pump starts and runs continuously. Ensure pump speed is under manual-operator control.

3.4.4.2.2 OFF

With the H-O-A switch in OFF position, the pump stops.

3.4.4.2.3 AUTO

With the H-O-A switch in AUTO position, run the pump subject to the Hot Water Pump Start/Stop (HW-PMP-SS) command and ensure pump speed is under control of the DDC system.

3.4.4.3 Proofs and Safeties

DDC Hardware must monitor all proofs and safeties.

3.4.4.3.1 Proofs

None

3.4.4.3.2 Safeties

None

3.4.4.3.3 DDC Hardware Reset

Reset all proofs and safeties via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

3.4.4.4 Pressure Control

When this loop is enabled modulate the pump variable frequency drive unit to maintain the pipe system pressure at setpoint as shown, as measured by the differential pressure tap and sensor as shown. When this loop is disabled, ensure the DDC Hardware capacity modulation output to the VFD is zero percent.

-- End of Section --

SECTION 23 11 20

FACILITY GAS PIPING
05/20

PART 1 GENERAL

1.1 SUMMARY

This specification section applies to gas piping installed within buildings incidental underground piping under building, above ground steel piping and corrugated stainless steel tubing (CSST) both outside (up to 5 feet beyond exterior walls) and within buildings in compliance with NFPA 54 /AGA Z223.1, "National Fuel Gas Code" , "Fuel Gas Piping".

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN GAS ASSOCIATION (AGA)

AGA XR0603 (2006; 8th Ed) AGA Plastic Pipe Manual for Gas Service

AGA Z223.1 (2012) National Fuel Gas Code

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI Z21.15/CSA 9.1 (2021) Manually Operated Gas Valves for Appliances, Appliance Connector Valves and Hose End Valves

ANSI Z21.24/CSA 6.10 (2022) Connectors for Gas Appliances

ANSI Z21.41/CSA 6.9 (2014; R 2019) Quick-Disconnect Devices for Use with Gas Fuel Appliances

ANSI Z21.69/CSA 6.16 (2015; R 2020) Connectors for Movable Gas Appliances

ANSI Z21.78/CSA 6.20 (2010; R 2020) Standard Specification for Combination Gas Controls for Gas Appliances

AMERICAN PETROLEUM INSTITUTE (API)

API 570 (2016; Addendum 1 2017; Addendum 2 2018; ERTA 1 2018) Piping Inspection Code: In-Service Inspection, Rating, Repair, and Alteration of Piping Systems

API RP 2009 (2002; R 2007; 7th Ed) Safe Welding, Cutting, and Hot Work Practices in Refineries, Gasoline Plants, and Petrochemical Plants

API Spec 6D (June 2018, 4th Ed; Errata 1 July 2018;

Errata 2 August 2018) Specification for
Pipeline and Piping Valves

API Std 598 (2009) Valve Inspecting and Testing
API Std 607 (2016) Fire Test for Quarter-turn Valves
and Valves Equipped with Non-metallic Seats

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE 25-16 (2016) Earthquake-Activated Automatic Gas
Shutoff Devices

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME A13.1 (2020) Scheme for the Identification of
Piping Systems
ASME B1.1 (2003; R 2018) Unified Inch Screw Threads
(UN and UNR Thread Form)
ASME B1.20.1 (2013; R 2018) Pipe Threads, General
Purpose (Inch)
ASME B16.21 (2021) Nonmetallic Flat Gaskets for Pipe
Flanges
ASME B16.33 (2012; R 2017) Manually Operated Metallic
Gas Valves for Use in Gas Piping Systems
Up to 125 psi, (Sizes NPS 1/2 - NPS 2)
ASME B18.2.1 (2012; Errata 2013) Square and Hex Bolts
and Screws (Inch Series)
ASME B18.2.2 (2022) Nuts for General Applications:
Machine Screw Nuts, and Hex, Square, Hex
Flange, and Coupling Nuts (Inch Series)
ASME B31.8 (2018; Supplement 2018) Gas Transmission
and Distribution Piping Systems
ASME B31.9 (2020) Building Services Piping
ASME BPVC SEC IX (2017; Errata 2018) BPVC Section
IX-Welding, Brazing and Fusing
Qualifications

AMERICAN WELDING SOCIETY (AWS)

AWS A5.8/A5.8M (2019) Specification for Filler Metals for
Brazing and Braze Welding
AWS WHB-2.9 (2004) Welding Handbook; Volume 2, Welding
Processes, Part 1

ASTM INTERNATIONAL (ASTM)

ASTM A193/A193M (2023) Standard Specification for
Alloy-Steel and Stainless Steel Bolting

Materials for High-Temperature Service and
Other Special Purpose Applications

ASTM A194/A194M	(2023) Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM F2015	(2000; R 2013) Standard Specification for Lap Joint Flange Pipe End Applications
CSA GROUP (CSA)	
ANSI LC 1/CSA 6.26	(2019) Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing (CSST)
CGA 3.11-M88	(2015) Lever Operated Pressure Lubricated Plug Type Gas Shut-Off Valves
FM GLOBAL (FM)	
FM APP GUIDE	(updated on-line) Approval Guide http://www.approvalguide.com/
MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)	
MSS SP-25	(2018) Standard Marking System for Valves, Fittings, Flanges and Unions
MSS SP-58	(2018) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation
NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)	
NFPA 54	(2024) National Fuel Gas Code
NFPA 58	(2020; TIA 20-1; TIA 20-2; TIA 20-3) Liquefied Petroleum Gas Code
NFPA 70	(2023; ERTA 7 2023; TIA 23-15) National Electrical Code
U.S. DEPARTMENT OF DEFENSE (DOD)	
MIL-STD-101	(2014; Rev C) Color Code for Pipelines and for Compressed Gas Cylinders
U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)	
49 CFR 192	Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards
UNDERWRITERS LABORATORIES (UL)	
UL FLAMMABLE & COMBUSTIBLE	(2012) Flammable and Combustible Liquids and Gases Equipment Directory

1.3 SYSTEM DESCRIPTION

The gas piping system includes natural gas piping and appurtenances from point of connection with supply system, as indicated, to gas operated equipment within the facility. Submit operation and maintenance data in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA, in three separate packages.

1.3.1 Gas Facility System and Equipment Operation

Include shop drawings showing piping layout, locations of system valves, gas line markers and cathodic protection system; step-by-step procedures for system start up, operation and shutdown (index system components and equipment to the system drawings); isolation procedures including valve operation to shutdown or isolate each section of the system (index valves to the system maps and provide separate procedures for normal operation and emergency shutdown if required to be different). Submit Data package No. 4.

1.3.2 Gas Facility System Maintenance

Include maintenance procedures and frequency for system and equipment; identification of pipe materials and manufacturer by locations, pipe repair procedures, and jointing procedures at transitions to other piping material or material from a different manufacturer. Submit Data Package No.4.

1.3.3 Gas Facility Equipment Maintenance

Include identification of valves, shut-offs, disconnects, and other equipment by materials, manufacturer, vendor identification and location; maintenance procedures and recommended tool kits for valves and equipment; recommended repair methods (i.e., field repair, factory repair, or replacement) for each valve and piece of equipment; and preventive maintenance procedures, possible failure modes and troubleshooting guide. Submit Data Package No. 3.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Gas Piping System; G

SD-03 Product Data

Pipe and Fittings; G

Gas Equipment Connectors; G

Gas Piping System; G

Pipe Coating Materials; G

Pressure Regulators; G

Risers; G

Transition Fittings; G

Valves; G

Warning and Identification Tape; G

SD-06 Test Reports

Testing; G

Pressure Tests; G

Test with Gas; G

SD-07 Certificates

Welders Procedures and Qualifications; G

Assigned Number, Letter, or Symbol; G

SD-08 Manufacturer's Instructions

PE Pipe and Fittings; G

Pipe Coating Materials; G

SD-10 Operation and Maintenance Data

Gas Facility System and Equipment Operation; G

Gas Facility System Maintenance; G

Gas Facility Equipment Maintenance; G

1.5 QUALITY ASSURANCE

Submit manufacturer's descriptive data and installation instructions for approval for compression-type mechanical joints used in joining dissimilar materials and for insulating joints. Mark all valves, flanges and fittings in accordance with MSS SP-25.

1.5.1 Welding Qualifications

- a. Weld piping in accordance with qualified procedures using performance qualified welders and welding operators in accordance with API RP 2009, ASME BPVC SEC IX, and ASME B31.9. Welding procedures qualified by others, and welders and welding operators qualified by another employer may be accepted as permitted by ASME B31.9. Notify the Contracting Officer at least 24 hours in advance of tests, and perform at the work site if practicable.

- b. Submit a certified copy of welders procedures and qualifications metal and PE in conformance with ASME B31.9 for each welder and welding operator. Submit the assigned number, letter, or symbol that will be used in identifying the work of each welder to the Contracting Officer.
Weld all structural members in accordance and in conformance with AWS A5.8/A5.8M, and AWS WHB-2.9.

1.5.2 Jointing Thermoplastic and Fiberglass Piping

Perform all jointing of piping using qualified joiners and qualified procedures in accordance with AGA XR0603. Furnish the Contracting Officer with a copy of qualified procedures and list of and identification symbols of qualified joiners. Submit manufacturer's installation instructions and manufacturer's visual joint appearance chart, including all PE pipe and fittings.

1.5.3 Shop Drawings

Submit drawings for complete Gas Piping System, within 30 days of contract award, showing location, size and all branches of pipeline; location of all required shutoff valves; and instructions necessary for the installation of gas equipment connectors and supports.

1.6 DELIVERY, STORAGE, AND HANDLING

1.6.1 Plastic Pipe

Handle, transport, and store plastic pipe and fittings carefully. Plug or cap pipe and fittings ends during transportation or storage to minimize dirt and moisture entry. Do not subject piping to abrasion or concentrated external loads. Discard PE pipe sections and fittings that have been damaged.

1.6.2 CSST Tubing

Handle, transport and store CSST tubing on the wooden spool or shipping container provided by the manufacturer. Insure tubing ends are capped during transportation and storage to minimize dirt and moisture entry. Discard any tubing segment and fitting that has been damaged.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

Provide materials and equipment which are the standard products of a manufacturer regularly engaged in the manufacture of the products and that essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening. Asbestos or products containing asbestos are not allowed. Submit catalog data and installation instructions for pipe, valves, all related system components, pipe coating materials and application procedures. Conform to NFPA 54 and with requirements specified herein. Provide supply piping to appliances or equipment at least as large as the inlets thereof.

2.2 GAS PIPING SYSTEM AND FITTINGS

2.2.1 Steel Pipe, Joints, and Fittings

2.2.2 Corrugated Stainless Steel Tubing, Fittings and Accessories

Provide corrugated stainless steel tubing conforming to ANSI LC 1/CSA 6.26 (austenitic stainless steel of series 300) with tubing joints made with special mechanical fittings as supplied by the tubing manufacturer.

2.2.2.1 Tubing

Austenitic stainless alloy of series 300 with polyethylene jacket/coating in accordance with ANSI LC 1/CSA 6.26 for sizes 3/8-inch through 2-inch

2.2.2.2 Mechanical Fittings

Copper alloy with one end matched to the corrugated tubing and one end with NPT threads in accordance with ASME B1.20.1

2.2.2.3 Striker Plates

Hardened steel designed to protect tubing from mechanical damage in accordance with ANSI LC 1/CSA 6.26

2.2.2.4 Manifolds

Malleable iron, steel or copper alloy with threaded connections/ports in accordance with ASME B1.20.1

2.2.3 Sealants for Steel Pipe Threaded Joints

Provide joint sealing compound as listed in UL FLAMMABLE & COMBUSTIBLE, Class 20 or less. For taping, use tetrafluoroethylene tape conforming to UL FLAMMABLE & COMBUSTIBLE.

2.2.4 Warning and Identification

Provide pipe flow markings, warning and identification tape, and metal tags as required.

2.2.5 Flange Gaskets

Provide gaskets of nonasbestos compressed material in accordance with ASME B16.21, 1/16 inch thickness, full face or self-centering flat ring type, containing aramid fibers bonded with styrene butadiene rubber (SBR) or nitrile butadiene rubber (NBR) suitable for a maximum 600 degree F service, to be used for hydrocarbon service.

2.2.6 Pipe Threads

Provide pipe threads conforming to ASME B1.20.1.

2.2.7 Escutcheons

Provide chromium-plated steel or chromium-plated brass escutcheons, either one piece or split pattern, held in place by internal spring tension or set screw.

2.2.8 Gas Transition Fittings

- c. Provide lever operated pressure lubricated plug type gas shut-off valve conforming to CGA 3.11-M88.

2.2.9 Insulating Pipe Joints

2.2.9.1 Insulating Joint Material

Provide insulating joint material between flanged or threaded metallic pipe systems where shown to control galvanic or electrical action.

2.2.9.2 Threaded Pipe Joints

Provide threaded pipe joints of steel body nut type dielectric unions with insulating gaskets.

2.2.9.3 Flanged Pipe Joints

Provide joints for flanged pipe consisting of full face sandwich-type flange insulating gasket of the dielectric type, insulating sleeves for flange bolts, and insulating washers for flange nuts. Provide lap joint flange pipe ends conforming to ASTM F2015.

2.2.10 Flexible Connectors

- a. Provide flexible connectors for connecting gas utilization equipment to building gas piping conforming to ANSI Z21.24/CSA 6.10 or ANSI Z21.41/CSA 6.9 for quick disconnect devices, and flexible connectors for movable food service equipment conforming to ANSI Z21.69/CSA 6.16. Provide combination gas controls for gas appliances conforming to ANSI Z21.78/CSA 6.20.
- b. Do not install the flexible connector through the appliance cabinet face. Provide rigid metallic pipe and fittings to extend the final connection beyond the cabinet, except when appliance is provided with an external connection point.

2.3 VALVES

Provide lockable shutoff or service isolation valves conforming to the following:

2.3.1 Valves 2 Inches and Smaller

Provide valves 2 inches and smaller conforming to ASME B16.33 of materials and manufacture compatible with system materials used.

2.3.2 Valves 2-1/2 Inches and Larger

Provide valves 2-1/2 inches and larger of carbon steel conforming to API Spec 6D, Class 150.

2.4 RISERS

Provide manufacturer's standard riser, transition from plastic to steel pipe with 7 to 12 mil thick epoxy coating. Use swaged gas-tight construction with O-ring seals, metal insert, and protective sleeve.

Provide wall-mounted riser supports .

2.5 PIPE HANGERS AND SUPPORTS

Provide pipe hangers and supports conforming to MSS SP-58.

2.6 LINE AND APPLIANCE REGULATORS AND SHUTOFF VALVES

Provide regulators conforming to ANSI Z21.78/CSA 6.20 for combination gas controls for gas appliances . Provide shutoff valves conforming to ANSI Z21.15/CSA 9.1 for manually controlled gas shutoff valves .

2.7 AUTOMATIC GAS SHUT-OFF

2.8 BOLTING (BOLTS AND NUTS)

Stainless steel bolting; ASTM A193/A193M, Grade B8M or B8MA, Type 316, for bolts; and ASTM A194/A194M, Grade 8M, Type 316, for nuts. Dimensions of bolts, studs, and nuts must conform with ASME B18.2.1 and ASME B18.2.2 with coarse threads conforming to ASME B1.1, with Class 2A fit for bolts and studs and Class 2B fit for nuts. Bolts or bolt-studs must extend through the nuts and may have reduced shanks of a diameter not less than the diameter at root of threads. Bolts must have American Standard regular square or heavy hexagon heads; nuts must be American Standard heavy semifinished hexagonal.

2.9 GASKETS

Fluorinated elastomer, compatible with flange faces.

2.10 IDENTIFICATION FOR ABOVEGROUND PIPING

MIL-STD-101 for legends and type and size of characters. For pipes 3/4 inch od and larger, provide printed legends to identify contents of pipes and arrows to show direction of flow. Color code label backgrounds to signify levels of hazard. Make labels of plastic sheet with pressure-sensitive adhesive suitable for the intended application. For pipes smaller than 3/4 inch od, provide brass identification tags 1 1/2 inches in diameter with legends in depressed black-filled characters.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy or areas of conflict before performing the work.

3.2 EXCAVATION AND BACKFILLING

Provide required excavation, backfilling, and compaction as specified in Section 31 00 00 EARTHWORK.

3.3 GAS PIPING SYSTEM

Provide a gas piping system from the point of delivery, defined as the outlet of the shutoff valve, as specified under "Gas Service" within this specification, to the connections to each gas utilization device that is

in compliance with NFPA 54NFPA 58..

3.3.1 Protection and Cleaning of Materials and Components

Protect equipment, pipe, and tube openings by closing with caps or plugs during installation. At the completion of all work, thoroughly clean the entire system.

3.3.2 Workmanship and Defects

Piping, tubing and fittings must be clear and free of cutting burrs and defects in structure or threading and must be thoroughly brushed and chip-and scale-blown. Repair of defects in piping, tubing or fittings is not allowed; replace defective items when found.

3.4 PROTECTIVE COVERING

3.4.1 Underground Metallic Pipe

Protect buried metallic piping and tubing from corrosion by either: (1) encasement in a water tight plastic conduit; or (2) encasement in a protective system designed and listed by the manufacturer for this application. When dissimilar metals are joined underground, use gastight insulating fittings.

3.4.2 Aboveground Metallic Piping Systems

3.4.2.1 Ferrous Surfaces

Touch up shop primed surfaces with ferrous metal primer. Solvent clean surfaces that have not been shop primed. Mechanically clean surfaces that contain loose rust, loose mill scale and other foreign substances by power wire brushing and prime with ferrous metal primer. Finish primed surfaces with two coats of exterior oil paint or vinyl paint.

3.4.2.2 Nonferrous Surfaces

Except for aluminum alloy pipe, do not paint nonferrous surfaces. Paint surfaces of aluminum alloy pipe and fittings to protect against external corrosion where they contact masonry, plaster, insulation, or are subject to repeated wettings by such liquids as water, detergents or sewage. Solvent-clean the surfaces and treat with vinyl type wash coat. Apply a first coat of aluminum paint and a second coat of alkyd gloss enamel or silicone alkyd copolymer enamel.

3.5 INSTALLATION

Install the gas system in conformance with the manufacturer's recommendations and applicable provisions of NFPA 54AGA XR0603, and as indicated. Perform all pipe cutting without damage to the pipe, with an approved type of mechanical cutter, unless otherwise authorized. Use wheel cutters where practicable. On steel pipe 6 inches and larger, an approved gas cutting and beveling machine may be used. Cut thermoplastic and fiberglass pipe in accordance with AGA XR0603.

3.5.1 Metallic Piping Installation

Bury underground piping a minimum of 18 inches below grade. Make changes in direction of piping with fittings only; mitering or notching pipe to

form elbows and tees or other similar type construction is not permitted. Branch connection may be made with either tees or forged branch outlet fittings. Provide branch outlet fittings which are forged, flared for improvement of flow where attached to the run, and reinforced against external strains. Do not use aluminum alloy pipe in exterior locations or underground.

3.5.2 Metallic Tubing Installation

Install metallic tubing using gas tubing fittings approved by the tubing manufacturer. CSST gas piping systems must be installed by contractors who have completed the manufacturer's training program as indicated on a certification card. Make branch connections with tees. Prepare all tubing ends with tools designed for that purpose. Do not use aluminum alloy tubing in exterior locations or underground. Maintain electrical continuity of gas piping system in accordance with NFPA 54 NFPA 58, paragraph entitled 'Electrical Bonding and Grounding'.

3.5.3 Thermoplastic and Fiberglass Piping, Tubing, and Fittings

Installation of thermoplastic and fiberglass piping, tubing, and fittings is permitted only outside and underground. Bury piping a minimum of 18 inches below grade. Install the piping to avoid excessive stresses due to thermal contraction, and use only where indicated. Installations must be made using qualified procedures, by qualified installers, and in compliance with AGA XR0603 and NFPA 54 NFPA 58, and must be inspected by a qualified inspector.

3.5.4 Connections Between Metallic and Plastic Piping

Connections between metallic and plastic piping are only allowed outside, underground, and with approved transition fittings.

3.5.5 Piping and Tubing Buried Under Buildings

Run underground piping and tubing installed beneath buildings in a steel pipe casing protected from corrosion installed within a water tight plastic conduit or as part of a listed encasement system. Extend casing or encasement system at least 4 inches outside the building, and provide the pipe with spacers and end bushings to seal at both ends to prevent the entrance of water and/or the escape of gas. Extend a vent line from the annular space above grade outside to a point where gas will not be a hazard, and terminate in a rain/insect-resistant fitting.

3.5.6 Concealed Piping in Buildings

Do not use combinations of fittings (unions, tubing fittings, running threads, right- and left-hand couplings, bushings, and swing joints) to conceal piping within buildings.

3.5.6.1 Piping and Tubing in Partitions

Locate concealed piping and tubing in hollow, rather than solid, partitions. Protect tubing passing through walls or partitions against physical damage both during and after construction, and provide appropriate safety markings and labels. Provide protection of concealed pipe and tubing in accordance with ANSI LC 1/CSA 6.26.

3.5.6.2 Piping in Floors

Lay piping in solid floors in channels suitably covered to permit access to the piping with minimum damage to the building.

3.5.7 Aboveground Piping

Run aboveground piping as straight as practicable along the alignment and elevation indicated, with a minimum of joints, and separately supported from other piping system and equipment. Install exposed horizontal piping no farther than 6 inches from nearest parallel wall and at an elevation which prevents standing, sitting, or placement of objects on the piping.

3.5.8 Final Gas Connections

Unless otherwise specified, make final connections with rigid metallic pipe and fittings. Flexible connectors may be used for final connections to gas utilization equipment. In addition to cautions listed in instructions required by ANSI standards for flexible connectors, insure that flexible connectors do not pass through equipment cabinet. Provide accessible gas shutoff valve and coupling for each gas equipment item.

3.5.9 Seismic Requirements

Support and brace piping and attached valves to resist seismic loads in conformance with ASCE 25-16. CSST tubing and fittings that are seismically qualified in accordance with the FM APP GUIDE: Flexible Piping Systems for Flammable Gases must meet the seismic requirements in accordance with the manufacturer's installation instructions.

3.6 PIPE JOINTS

Design and install pipe joints to effectively sustain the longitudinal pull-out forces caused by contraction of the piping or superimposed loads.

3.6.1 Threaded Metallic Joints

Provide threaded joints in metallic pipe with tapered threads evenly cut and made with UL approved graphite joint sealing compound for gas service or tetrafluoroethylene tape applied to the male threads only. Threaded joints up to 1-1/2 inches in diameter may be made with approved tetrafluoroethylene tape. Threaded joints up to 2 inches in diameter may be made with approved joint sealing compound. After cutting and before threading, ream pipe and remove all burrs. Caulking of threaded joints to stop or prevent leaks is not permitted.

3.6.2 Welded Metallic Joints

Conform beveling, alignment, heat treatment, and inspection of welds to NFPA 54. Remove weld defects and make repairs to the weld, or remove the weld joints entirely and reweld. After filler metal has been removed from its original package, protect and store so that its characteristics or welding properties are not affected adversely. Do not use electrodes that have been wetted or have lost any of their coating.

3.6.3 Thermoplastic and Fiberglass Joints

3.6.3.1 Thermoplastic and Fiberglass

Conform jointing procedures to AGA XR0603. Do not make joints with solvent cement or heat of fusion between different kinds of plastics.

3.6.3.2 PE Fusion Welding Inspection

Visually inspect butt joints by comparing with, manufacturer's visual joint appearance chart. Inspect fusion joints for proper fused connection. Replace defective joints by cutting out defective joints or replacing fittings. Inspect, in conformance with API 570, 100 percent of all joints and re-inspect all corrections. Arrange with the pipe manufacturer's representative in the presence of the Contracting Officer to make first time inspection.

3.6.4 Flared Metallic Tubing Joints

Make flared joints in metallic tubing with special tools recommended by the tubing manufacturer. Use flared joints only in systems constructed from nonferrous pipe and tubing, when experience or tests have demonstrated that the joint is suitable for the conditions, and when adequate provisions are made in the design to prevent separation of the joints. Do not use metallic ball sleeve compression-type tubing fittings for tubing joints.

3.6.5 Solder or Brazed Joints

Make all joints in metallic tubing and fittings with materials and procedures recommended by the tubing supplier. Braze joints with material having a melting point above 1000 degrees F, containing no phosphorous.

3.6.6 Joining Thermoplastic or Fiberglass to Metallic Piping or Tubing

When compression type mechanical joints are used, provide gasket material in the fittings compatible with the plastic piping and with the gas in the system. Use an internal tubular rigid stiffener in conjunction with the fitting, flush with end of the pipe or tubing, extending at least to the outside end of the compression fitting when installed. Remove all rough or sharp edges from stiffener. Do not force fit stiffener in the plastic. Split tubular stiffeners are not allowed.

3.6.7 Press Connections

Make press connections in accordance with manufacturer's installation instructions using tools approved by the manufacturer. Fully insert the tubing into the fitting and then mark at the shoulder of the fitting. Check the fitting alignment against the mark on the tubing to assure the tubing is fully inserted before the joint is pressed.

3.7 PIPE SLEEVES

Provide pipes passing through concrete or masonry walls or concrete floors or roofs with pipe sleeves fitted into place at the time of construction. Do not install sleeves in structural members except where indicated or approved. Make all rectangular and square openings as detailed. Extend each sleeve through its respective wall, floor or roof, and cut flush with each surface, except in mechanical room floors not located on grade where

clamping flanges or riser pipe clamps are used. Extend sleeves in mechanical room floors above grade at least 4 inches above finish floor. Unless otherwise indicated, use sleeves large enough to provide a minimum clearance of 1/4 inch all around the pipe. Provide steel pipe for sleeves in bearing walls, waterproofing membrane floors, and wet areas. Provide sleeves in nonbearing walls, floors, or ceilings of steel pipe, galvanized sheet metal with lock-type longitudinal seam, or moisture-resistant fiber or plastic. For penetrations of fire walls, fire partitions and floors which are not on grade, seal the annular space between the pipe and sleeve with fire-stopping material and sealant that meet the requirement of Section 07 84 00 FIRESTOPPINGG.

3.8 PIPES PENETRATING WATERPROOFING MEMBRANES

Install pipes penetrating waterproofing membranes as specified in Section 22 00 00 PLUMBING, GENERAL PURPOSE.

3.9 FIRE SEAL

Fire seal all penetrations of fire rated partitions, walls and floors in accordance with Section 07 84 00 FIRESTOPPING.

3.10 ESCUTCHEONS

Provide escutcheons for all finished surfaces where gas piping passes through floors, walls, or ceilings except in boiler, utility, or equipment rooms.

3.11 SPECIAL REQUIREMENTS

Provide drips, grading of the lines, freeze protection, and branch outlet locations as shown and conforming to the requirements of NFPA 54.

3.12 BUILDING STRUCTURE

Do not weaken any building structure by the installation of any gas piping. Do not cut or notch beams, joists or columns. Attach piping supports to metal decking. Do not attach supports to the underside of concrete filled floors or concrete roof decks unless approved by the Contracting Officer.

3.13 PIPING SYSTEM SUPPORTS

Support gas piping systems in buildings with pipe hooks, metal pipe straps, bands or hangers suitable for the size of piping or tubing. Do not support any gas piping system by other piping. Conform spacing of supports in gas piping and tubing installations to the requirements of NFPA 54. Conform the selection and application of supports in gas piping and tubing installations to the requirements of MSS SP-58. In the support of multiple pipe runs on a common base member, use a clip or clamp where each pipe crosses the base support member. Spacing of the base support members is not to exceed the hanger and support spacing required for any of the individual pipes in the multiple pipe run. Rigidly connect the clips or clamps to the common base member. Provide a clearance of 1/8 inch between the pipe and clip or clamp for all piping which may be subjected to thermal expansion.

3.14 ELECTRICAL BONDING AND GROUNDING

Provide a gas piping system within the building that is electrically continuous and bonded to a grounding electrode as required by NFPA 54, NFPA 58, and NFPA 70.

3.15 SHUTOFF VALVE

Install the main gas shutoff valve controlling the gas piping system to be easily accessible for operation, as indicated, protected from physical damage, and marked with a metal tag to clearly identify the piping system controlled. Install valves approximately at locations indicated. Orient stems vertically, with operators on top, or horizontally. Provide stop valve on service branch at connection to main and shut-off valve on riser outside of building.

3.16 LINE AND APPLIANCE PRESSURE REGULATORS

Install line pressure regulators and appliance regulators in accordance with the manufacturer's requirements and in accordance with NFPA 54/NFPA 58. Install each regulator in an accessible location and install shutoff valves ahead of each line and appliance regulator to allow for maintenance. Where vent limiting devices are not included in the regulators, install a vent pipe to the exterior of the building. Terminate all service regulator vents and relief vents in the outside air in rain and insect resistant fittings. Locate the open end of the vent where gas can escape freely into the atmosphere, away from any openings into the building and above areas subject to flooding.

3.17 GAS SERVICE INSTALLATION

Gas service line, service regulator and gas company meter must be installed in accordance with 49 CFR 192 and ASME B31.8. Contractor must submit and use only tested and approved work procedures. Contractor must use only welders and jointers who have been recently qualified by training and test for joining and installing the gas pipe material used on this job. The finished product must be inspected by a person qualified to inspect joints made by the particular procedures used to make joints.

3.17.1 Service Line

Install service line, branch connection to the main, and riser in accordance with 49 CFR 192 and ASME B31.8. Provide a minimum of 18 inches cover or encase the service line so that it is protected. Install service line so that no undue stress is applied to the pipe, connection, or riser. Install approved riser and terminate with an approved isolation valve, EFV and automatic shutoff device. After laying of pipe and testing, backfill the trench in accordance with Section 31 00 00 EARTHWORK.

Where steel pipe is used as service line, install corrosion prevention coating and cathodic protect for the steel service line. Where connected to an existing cathodically protected steel pipe, ensure electrical continuity from the riser to the branch connection to the main. Install a dielectric fitting on the riser to prevent electrical continuity to the above ground piping.

Where plastic pipe is used as the service line, make joints in accordance with procedures qualified by test. Personnel joining plastic pipe must be

qualified by making a satisfactory specimen joint that passes the required inspection and test listed in 49 CFR 192.285. Inspection must be made by inspectors qualified in evaluating joints made under the specific joining procedure, as required by 49 CFR 192.287.

3.17.2 Service Regulator

Install service regulator in accordance with 49 CFR 192 and ASME B31.8 and this specification ensuring that the customer's piping is protected from over pressurization should the service regulator fail. A 3/8 inch tapped fitting equipped with a plug must be provided on both sides of the service regulator for installation of pressure gauges for adjusting the regulator. For inside installations, route the regulator vent pipe through the exterior wall to the atmosphere, and seal building penetrations for service line and vent. Terminate the regulator vent so that it is protected from precipitation and insect intrusion, so that it is not submerged during floods, and so that gas escaping will not create a hazard or enter the building through openings.

3.17.3 Gas Meter

Install shutoff valve, meter set assembly, and service regulator on the service line outside the building, 18 inches above the finished floor on the riser. An insulating joint (dielectric connection) must be installed on the inlet side of the meter set assembly and service regulator and must be constructed to prevent flow of electrical current.

3.18 CATHODIC PROTECTION

Provide cathodic protection for underground ferrous gas piping as specified in .

3.19 TESTING

Submit test procedures and reports in booklet form tabulating test and measurements performed; dated after award of this contract, and stating the Contractor's name and address, the project name and location, and a list of the specific requirements which are being certified. Test entire gas piping system to ensure that it is gastight prior to putting into service. Prior to testing, purge the system, clean, and clear all foreign material. Test each joint with an approved gas detector, soap and water, or an equivalent nonflammable solution. Inspect and test each valve in conformance with API Std 598 and API Std 607. Complete testing before any work is covered, enclosed, or concealed, and perform with due regard for the safety of employees and the public during the test. Install bulkheads, anchorage and bracing suitably designed to resist test pressures if necessary, and as directed and or approved by the Contracting Officer. Do not use oxygen as a testing medium.

3.19.1 Pressure Tests

Submit test procedures and reports in booklet form tabulating test and measurements performed; dated after award of this contract, and stating the Contractor's name and address, the project name and location, and a list of the specific requirements which are being certified. Before appliances are connected, test by filling the piping systems with air or an inert gas to withstand a minimum pressure of 3 pounds gauge for a period of not less than 10 minutes as specified in NFPA 54 without showing any drop in pressure. Do not use Oxygen for test. Measure pressure with

a mercury manometer, slope gauge, or an equivalent device calibrated to be read in increments of not greater than 0.1 pound. Isolate the source of pressure before the pressure tests are made.

3.19.2 Test With Gas

Before turning on gas under pressure into any piping, close all openings from which gas can escape. Immediately after turning on the gas, check the piping system for leakage by using a laboratory-certified gas meter, an appliance orifice, a manometer, or equivalent device. Conform all testing to the requirements of NFPA 54. If leakage is recorded, shut off the gas supply, repair the leak, and repeat the tests until all leaks have been stopped.

3.19.3 Purging

After testing is completed, and before connecting any appliances, fully purge all gas piping. Do not purge piping into the combustion chamber of an appliance. Do not purge the open end of piping systems into confined spaces or areas where there are ignition sources unless the safety precautions recommended in NFPA 54 are followed.

3.19.4 Labor, Materials and Equipment

Furnish all labor, materials and equipment necessary for conducting the testing and purging.

3.20 PIPE COLOR CODE MARKING

Provide color code marking of piping as specified in Section 09 90 00 PAINTS AND COATINGS, conforming to ASME A13.1.

-- End of Section --

SECTION 23 23 00

REFRIGERANT PIPING

08/21

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR-CONDITIONING, HEATING AND REFRIGERATION INSTITUTE (AHRI)

AHRI 710 I-P	(2009) Performance Rating of Liquid-Line Driers
AHRI 720	(2002) Refrigerant Access Valves and Hose Connectors
AHRI 750 I-P	(2016) Performance Rating of Thermostatic Refrigerant Expansion Valves
AHRI 760 I-P	(2014) Performance Rating of Solenoid Valves for Use with Volatile Refrigerants
AHRI 1370 I-P	(2017) Performance Rating of Electronic Expansion Valves

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE 15 & 34	(2013) ASHRAE Standard 34-2016 Safety Standard for Refrigeration Systems/ASHRAE Standard 34-2016 Designation and Safety Classification of Refrigerants-ASHRAE Standard 34-2016
ASHRAE 17	(2015) Method of Testing Capacity of Thermostatic Refrigerant Expansion Valves
ASHRAE 90.1 - IP	(2019) Energy Standard for Buildings Except Low-Rise Residential Buildings

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B16.22	(2021) Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B16.26	(2018) Standard for Cast Copper Alloy Fittings for Flared Copper Tubes
ASME B31.1	(2022) Power Piping
ASME B31.5	(2022) Refrigeration Piping and Heat Transfer Components

ASME B40.100 (2022) Pressure Gauges and Gauge Attachments

ASME BPVC SEC IX (2017; Errata 2018) BPVC Section IX-Welding, Brazing and Fusing Qualifications

AMERICAN WELDING SOCIETY (AWS)

AWS A5.8/A5.8M (2019) Specification for Filler Metals for Brazing and Braze Welding

AWS A5.31/A5.31M (2012) Specification for Fluxes for Brazing and Braze Welding

AWS BRH (2007; 5th Ed) Brazing Handbook

AWS D1.1/D1.1M (2020; Errata 1 2021) Structural Welding Code - Steel

AWS Z49.1 (2021) Safety in Welding and Cutting and Allied Processes

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M (2022) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

ASTM A653/A653M (2023) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

ASTM B62 (2017) Standard Specification for Composition Bronze or Ounce Metal Castings

ASTM B75/B75M (2020) Standard Specification for Seamless Copper Tube

ASTM B117 (2019) Standard Practice for Operating Salt Spray (Fog) Apparatus

ASTM B280 (2020) Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service

ASTM D520 (2000; R 2011) Zinc Dust Pigment

ASTM D3308 (2012; R 2017) Standard Specification for PTFE Resin Skived Tape

ASTM E84 (2023) Standard Test Method for Surface Burning Characteristics of Building Materials

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS
INDUSTRY (MSS)

MSS SP-58 (2018) Pipe Hangers and Supports -
Materials, Design and Manufacture,
Selection, Application, and Installation

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-301-01 (2023; with Change 1, 2023) Structural
Engineering

1.2 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Refrigerant Piping System; G

SD-03 Product Data

Refrigerant Piping System

Spare Parts

Qualifications

Refrigerant Piping Tests

Verification of Dimensions

SD-06 Test Reports

Refrigerant Piping Tests

SD-07 Certificates

Service Organization

SD-10 Operation and Maintenance Data

Maintenance; G

Operation and Maintenance Manuals; G

Demonstrations; G

1.3 QUALITY ASSURANCE

1.3.1 Qualifications

Submit 2 copies of qualified procedures, and list of names and identification symbols of qualified welders and welding operators, prior

to non-factory welding operations. Weld piping in accordance with the qualified procedures using performance qualified welders and welding operators. Procedures and welders must be qualified in accordance with ASME BPVC SEC IX. Welding procedures qualified by others, and welders and welding operators qualified by another employer may be accepted as permitted by ASME B31.1. Notify the Contracting Officer 24 hours in advance of tests to be performed at the work site, if practical. The welder or welding operator must apply the personally assigned symbol near each weld made, as a permanent record.

1.3.2 Contract Drawings

Because of the small scale of the drawings, it is not possible to indicate all offsets, fittings, and accessories that may be required. Carefully investigate the plumbing, fire protection, electrical, structural and finish conditions that would affect the work to be performed and arrange such work accordingly, furnishing required offsets, fittings, and accessories to meet such conditions.

1.4 DELIVERY, STORAGE, AND HANDLING

Protect stored items from the weather, humidity and temperature variations, dirt and dust, or other contaminants. Proper protection and care of all material both before and during installation is the Contractor's responsibility. Replace any materials found to be damaged at the Contractor's expense. During installation, cap piping and similar openings to keep out dirt and other foreign matter.

1.5 MAINTENANCE

1.5.1 General

Submit Data Package 2 plus operation and maintenance data complying with the requirements of Section 01 78 23 OPERATION AND MAINTENANCE DATA and as specified herein.

1.5.2 Extra Materials

Submit spare parts data for each different item of equipment specified, after approval of detail drawings and not later than 1 months prior to the date of beneficial occupancy. Include a complete list of parts and supplies, with current unit prices and source of supply, a recommended spare parts list for 1 year of operation, and a list of the parts recommended by the manufacturer to be replaced on a routine basis in the data.

PART 2 PRODUCTS

2.1 STANDARD COMMERCIAL PRODUCTS

- a. Provide materials and equipment which are standard products of a manufacturer regularly engaged in the manufacturing of such products, that are of a similar material, design and workmanship and that have been in satisfactory commercial or industrial use for 2 years prior to bid opening.
- b. The 2 year use must include applications of equipment and materials under similar circumstances and of similar size. The 2 years' experience must be satisfactorily completed by a product which has

been sold or is offered for sale on the commercial market through advertisements, manufacturer's catalogs, or brochures. Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation, for not less than 6000 hours exclusive of the manufacturer's factory tests, can be shown.

- c. Products must be supported by a service organization. System components must be environmentally suitable for the indicated locations. Submit a certified list of qualified permanent service organizations for support of the equipment which includes their addresses and qualifications. The service organizations must be reasonably convenient to the equipment installation and be able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.
- d. Exposed equipment moving parts, parts that produce high operating temperature, parts which may be electrically energized, and parts that may be a hazard to operating personnel must be insulated, fully enclosed, guarded, or fitted with other types of safety devices. Install safety devices so that proper operation of equipment is not impaired. Welding and cutting safety requirements must be in accordance with AWS Z49.1.
- e. Provide the manufacturer's standard catalog data, at least 5 weeks prior to the purchase or installation of a particular component. Highlight the data to show information such as, but not limited to, material, size, options, performance charts, and curves in adequate detail to demonstrate compliance with contract requirements. Include the manufacturer's recommended installation instructions and procedures in the data provided. Provide data for the following components as a minimum:
 - (1) Piping and Fittings
 - (2) Valves
 - (3) Piping Accessories
 - (4) Pipe Hangers, Inserts, and Supports

2.2 ELECTRICAL WORK

Electrical equipment and wiring must be in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Field wiring must be in accordance with manufacturer's instructions. Manual or automatic control and protective or signal devices required for the operation specified and any control wiring required for controls and devices specified, but not shown, must be provided.

2.3 REFRIGERANT PIPING SYSTEM

Provide refrigerant piping, valves, fittings, and accessories in accordance with ASHRAE 15 & 34 and ASME B31.5, except as specified herein. Refrigerant piping, valves, fittings, and accessories must be compatible with the fluids used and capable of withstanding the pressures and temperatures of the service. Refrigerant piping, valves, and accessories used for refrigerant service must be cleaned, dehydrated, and sealed (capped or plugged) prior to shipment from the manufacturer's plant. Submit drawings, at least 5 weeks prior to beginning construction, provided in adequate detail to demonstrate compliance with contract requirements. Drawings must consist of:

- a. Piping layouts which identify all valves and fittings.
- b. Plans and elevations which identify clearances required for maintenance and operation.

2.4 PIPE, FITTINGS AND END CONNECTIONS (JOINTS)

2.4.1 Copper Tubing

Provide copper tubing conforming to ASTM B280 annealed or hard drawn as required. Copper tubing must bear the product identification markings in accordance with ASTM B280, "ACR" must be present on copper tubing. Copper tubing must be soft annealed where bending is required and hard drawn where no bending is required. Soft annealed copper tubing must not be used in sizes larger than 1-3/8 inches. Joints must be brazed except that joints on lines 7/8 inch and smaller may be flared. Cast copper alloy fittings for flared copper tube must conform to ASME B16.26 and ASTM B62. Wrought copper and bronze solder-joint pressure fittings must conform to ASME B16.22 and ASTM B75/B75M. Joints and fittings for brazed joint must be wrought-copper or forged-brass sweat fittings. Cast sweat-type joints and fittings are not allowed for brazed joints. Brass or bronze adapters for brazed tubing may be used for connecting tubing to flanges and to threaded ends of valves and equipment.

2.4.2 Brazing Filler Metal

Filler metal must conform to AWS A5.8/A5.8M, Type BAg-5 with AWS Type FB3-A or Type FB3-C flux, except Type BCuP-3, BCuP-4, or BCuP-5 may be used for brazing copper-to-copper joints. BA1Si-4 with AWS Type FB1-A flux may be used when joining copper piping to aluminum components.

2.4.3 Brazing Flux

Brazing flux must conform to AWS A5.31/A5.31M, Type FB3-A or Type FB3-C when using Type BAg-5 filler metal. Type FB1-A is to be used with Type BA1Si-4 filler metal.

2.5 VALVES

Valves must be designed, manufactured, and tested specifically for refrigerant service. The valve material and all internal components must be compatible with the specific refrigerant and lubricant used. Valve bodies must be of brass, bronze, steel, or ductile iron construction. Valves 1 inch and smaller must have brazed or socket welded connections. Valves larger than 1 inch must have butt welded end connections. Do not use threaded end connections, except in pilot pressure or gauge lines where maintenance disassembly is required and welded flanges cannot be used. Internal parts must be removable for inspection or replacement without applying heat or breaking pipe connections. Valve stems exposed to the atmosphere must be stainless steel or corrosion resistant metal plated carbon steel. Direction of flow must be legibly and permanently indicated on the valve body. Control valve inlets must be fitted with integral or adapted strainer or filter where recommended or required by the manufacturer. Purge, charge and receiver valves must be of manufacturer's standard configuration.

2.5.1 Refrigerant Stop Valves

Valve must be the globe or full-port ball type with a back-seating stem

especially packed for refrigerant service. Valve packing must be replaceable under line pressure. Provide valve with a wrench operator and a seal cap. Valve must be the straight or angle pattern design as indicated.

2.5.2 Check Valves

Valve must be the swing or lift type as required to provide positive shutoff at the differential pressure indicated. Valve must be provided with resilient seat.

2.5.3 Liquid Solenoid Valves

Provide valves that comply with AHRI 760 I-P and are suitable for continuous duty with applied voltages 15 percent under and 5 percent over nominal rated voltage at maximum and minimum encountered pressure and temperature service conditions. Valves must be direct-acting or pilot-operating type, packless, except that packed stem, seal capped, manual lifting provisions must be furnished. Provide solenoid coils that are moisture-proof, UL approved, totally encapsulated or encapsulated and metal jacketed as required. Valves must have safe working pressure of 610 psi and a maximum operating pressure differential of at least 200 psi at 85 percent rated voltage. Valves must have an operating pressure differential suitable for the refrigerant used.

2.5.4 Expansion Valves

Provide valve conforming to AHRI 750 I-P and ASHRAE 17. Valve must be the diaphragm and spring-loaded type with internal or external equalizers, and bulb and capillary tubing. Provide valve with an external superheat adjustment along with a seal cap. Internal equalizers may be utilized where flowing refrigerant pressure drop between outlet of the valve and inlet to the evaporator coil is negligible and pressure drop across the evaporator is less than the pressure difference corresponding to 2 degrees F of saturated suction temperature at evaporator conditions. Bulb charge must be determined by the manufacturer for the application and such that liquid will remain in the bulb at all operating conditions. Do not use gas limited liquid charged valves and other valve devices for limiting evaporator pressure without a distributor or discharge tube or effective means to prevent loss of control when bulb becomes warmer than valve body. Pilot-operated valves must have a characterized plug to provide required modulating control. A de-energized solenoid valve may be used in the pilot line to close the main valve in lieu of a solenoid valve in the main liquid line. Provide an isolatable pressure gauge in the pilot line, at the main valve. Automatic pressure reducing or constant pressure regulating expansion valves may be used only where indicated or for constant evaporator loads.

2.5.5 Electronic Expansion Valves

Valve must conform to AHRI 1370 I-P and ASHRAE 17. The valve must prevent the return of liquid to the compressor in the event of power loss or low superheat.

2.5.6 Safety Relief Valves

Valve must be the two-way type, unless indicated otherwise. Valve must bear the ASME code symbol. Valve capacity must be certified by the National Board of Boiler and Pressure Vessel Inspectors. Valve must be of

an automatically reseating design after activation.

2.5.7 Evaporator Pressure Regulators, Direct-Acting

Valve must include a diaphragm/spring assembly, external pressure adjustment with seal cap, and pressure gauge port. Valve must maintain a constant inlet pressure by balancing inlet pressure on diaphragm against an adjustable spring load. Pressure drop at system design load must not exceed the pressure difference corresponding to a 2 degrees F change in saturated refrigerant temperature at evaporator operating suction temperature. Spring must be selected for indicated maximum allowable suction pressure range.

2.5.8 Refrigerant Access Valves

Provide refrigerant access valves and hose connections in accordance with AHRI 720.

2.6 PIPING ACCESSORIES

2.6.1 Filter Driers

Driers must conform to AHRI 710 I-P. Sizes 5/8 inch and larger must be the full flow, replaceable core type. Sizes 1/2 inch and smaller must be the sealed type. Cores must be of suitable desiccant that will not plug, cake, dust, channel, or break down, and must remove water, acid, and foreign material from the refrigerant. Construct filter driers so that none of the desiccant will pass into the refrigerant lines. Minimum bursting pressure must be 1,500 psi.

2.6.2 Sight Glass and Liquid Level Indicator

2.6.2.1 Assembly and Components

Assembly must be pressure- and temperature-rated and constructed of materials suitable for the service. Glass must be borosilicate type. Ferrous components subject to condensation must be electro-galvanized.

2.6.2.2 Gauge Glass

Gauge glass must include top and bottom isolation valves fitted with automatic checks, and packing followers; red-line or green-line gauge glass; elastomer or polymer packing to suit the service; and gauge glass guard.

2.6.2.3 Bull's-Eye and Inline Sight Glass Reflex Lens

Provide bull's-eye and inline sight glass reflex lens for dead-end liquid service. For pipe line mounting, provide two plain lenses in one body suitable for backlighting viewing.

2.6.2.4 Moisture Indicator

Indicator must be a self-reversible action, moisture reactive, color changing media. Indicator must be furnished with full-color-printing tag containing color, moisture, and temperature criteria. Unless otherwise indicated, the moisture indicator must be an integral part of each corresponding sight glass.

2.6.3 Vibration Dampeners

Dampeners must be of the all-metallic bellows and woven-wire type.

2.6.4 Flexible Pipe Connectors

Connector must be a composite of interior corrugated phosphor bronze or Type 300 Series stainless steel, as required for fluid service, with exterior reinforcement of bronze, stainless steel or monel wire braid. Assembly must be constructed with a safety factor of not less than 4 at 300 degrees F. Unless otherwise indicated, the length of a flexible connector must be as recommended by the manufacturer for the service intended.

2.6.5 Strainers

Strainers used in refrigerant service must have brass or cast-iron body, Y-or angle-pattern, cleanable, not less than 60-mesh noncorroding screen of an area to provide net free area not less than ten times the pipe diameter with pressure rating compatible with the refrigerant service. Screens must be stainless steel or monel and reinforced spring-loaded where necessary for bypass-proof construction.

2.6.6 Pressure and Vacuum Gauges

Provide gauges conforming to ASME B40.100 with throttling type needle valve or a pulsation dampener and shut-off valve. Gauge must be a minimum of 3-1/2 inches in diameter with a range from 0 psig to approximately 1.5 times the maximum system working pressure. Select each gauge range so that at normal operating pressure, the needle is within the middle-third of the range.

2.6.7 Temperature Gauges

Provide industrial duty type temperature gauges for the required temperature range. Gauges must have Fahrenheit scale in 2 degrees graduations scale (black numbers) on a white face. The pointer must be adjustable. Provide rigid stem type temperature gauges in thermowells located within 5 feet of the finished floor. Provide universal adjustable angle type or remote element type temperature gauges in thermowells located 5 to 7 feet above the finished floor. Provide remote element type temperature gauges in thermowells located 7 feet above the finished floor.

2.6.7.1 Stem Cased-Glass

Provide stem cased-glass case composed of polished stainless steel or cast aluminum, 9 inches long, with clear acrylic lens, and non-mercury filled glass tube with indicating-fluid column.

2.6.7.2 Bimetallic Dial

Provide bimetallic dial type case that is greater than 3-1/2 inches, stainless steel, and hermetically sealed with clear acrylic lens. Bimetallic element must be silicone dampened and unit fitted with external calibrator adjustment. Accuracy must be one percent of dial range.

2.6.7.3 Liquid-, Solid-, and Vapor-Filled Dial

Provide liquid-, solid-, and vapor-filled dial type cases that are greater than 3-1/2 inches, stainless steel or cast aluminum with clear acrylic

lens. Fill must be nonmercury, suitable for encountered cross-ambients, and connecting capillary tubing must be double-braided bronze.

2.6.7.4 Thermowell

Thermowell must be identical size, 1/2 or 3/4 inch NPT connection, brass or stainless steel. Where test wells are indicated, provide captive plug-fitted type 1/2 inch NPT connection suitable for use with either engraved stem or standard separable socket thermometer or thermostat. Mercury must not be used in thermometers. Extended neck thermowells must be of sufficient length to clear insulation thickness by 1 inch.

2.6.8 Pipe Hangers, Inserts, and Supports

Provide pipe hangers, inserts, guides, and supports conforming to MSS SP-58.

2.6.9 Escutcheons

Escutcheons must be chromium-plated iron or chromium-plated brass, either one piece or split pattern, held in place by internal spring tension or set screws.

2.7 FABRICATION

2.7.1 Factory Coating

Unless otherwise specified, equipment and component items, when fabricated from ferrous metal, must be factory finished with the manufacturer's standard finish, except that items located outside of buildings must have weather resistant finishes that will withstand 125 hours exposure to the salt spray test specified in ASTM B117 using a 5 percent sodium chloride solution. Immediately after completion of the test, the specimen must show no signs of blistering, wrinkling, cracking, or loss of adhesion and no sign of rust creepage beyond 1/8 inch on either side of the scratch mark. Cut edges of galvanized surfaces where hot-dip galvanized sheet steel is used must be coated with a zinc-rich coating conforming to ASTM D520, Type I.

2.7.2 Factory Applied Insulation

Factory installed insulation must be in accordance with ASHRAE 90.1 - IP. Refrigerant suction lines between the cooler and each compressor must be insulated with not less than 1/2 inch thick unicellular plastic foam. Factory insulated items installed outdoors are not required to be fire-rated. As a minimum, factory insulated items installed indoors must have a flame spread index no higher than 25 and a smoke developed index no higher than 50. Factory insulated items (no jacket) installed indoors and which are located in air plenums, in ceiling spaces, and in attic spaces must have a flame spread index no higher than 25 and a smoke developed index no higher than 50. Flame spread and smoke developed indexes must be determined by ASTM E84. Test insulation in the same density and installed thickness as the material to be used in the actual construction. Test material supplied by a manufacturer with a jacket as a composite material. Provide jackets, facings, and adhesives that have a flame spread index less than 25 and a smoke developed index less than 50 when tested in accordance with ASTM E84.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with all details of the work, perform a verification of dimensions in the field. Submit a letter, at least 2 weeks prior to beginning construction, including the date the site was visited, conformation of existing conditions, and any discrepancies found before performing any work.

3.2 INSTALLATION

Pipe and fitting installation must conform to the requirements of ASME B31.1. Cut pipe accurately to measurements established at the jobsite, and work into place without springing or forcing, completely clearing all windows, doors, and other openings. Cutting or other weakening of the building structure to facilitate piping installation is not permitted without written approval. Cut pipe or tubing square, remove by reaming, and permit free expansion and contraction without causing damage to the building structure, pipe, joints, or hangers.

3.2.1 Directional Changes

Make changes in direction with fittings, except that bending of pipe 4 inches and smaller is permitted, provided a pipe bender is used and wide weep bends are formed. Mitering or notching pipe or other similar construction to form elbows or tees is not permitted. The centerline radius of bends must not be less than 6 diameters of the pipe. Bent pipe showing kinks, wrinkles, flattening, or other malformations will not be accepted.

3.2.2 Functional Requirements

Install piping 1/2 inch/10 feet of pipe in the direction of flow to ensure adequate oil drainage. Properly cap or plug open ends of refrigerant lines or equipment during installation to keep moisture, dirt, or other foreign material out of the system. Piping must remain capped until installation. Equipment piping must be in accordance with the equipment manufacturer's recommendations and the contract drawings. Equipment and piping arrangements must fit into space allotted and allow adequate acceptable clearances for installation, replacement, entry, servicing, and maintenance.

3.2.3 Fittings and End Connections

3.2.3.1 Threaded Connections

Make threaded connections with tapered threads and make tight with PTFE tape complying with ASTM D3308 or equivalent thread-joint compound applied to the male threads only. Do not show more than three threads after the joint is made.

3.2.3.2 Brazed Connections

Perform brazing in accordance with AWS BRH, except as modified herein. During brazing, fill the pipe and fittings with a pressure regulated inert gas, such as nitrogen, to prevent the formation of scale. Before brazing copper joints, clean both the outside of the tube and the inside of the fitting with a wire fitting brush until the entire joint surface is bright

and clean. Do not use brazing flux on copper-to-copper connections. Remove surplus brazing material at all joints. Make steel tubing joints in accordance with the manufacturer's recommendations. Paint joints in steel tubing with the same material as the baked-on coating within 8 hours after joints are made. Protect tubing against oxidation during brazing by continuous purging of the inside of the piping using nitrogen. Support piping prior to brazing and do not spring or force.

3.2.3.3 Welded Connections

Fusion-weld joints in steel refrigerant piping. Make branch connections with welding tees or forged welding branch outlets. Thoroughly clean pipe of all scale and foreign matter before the piping is assembled. During welding, fill the pipe and fittings with an inert gas, such as nitrogen, to prevent the formation of scale. Beveling, alignment, heat treatment, and inspection of weld must conform to ASME B31.1. Remove and reweld weld defects at no additional cost to the Government. Store and dry electrodes in accordance with AWS D1.1/D1.1M or as recommended by the manufacturer. Do not use electrodes that have been wetted or that have lost any of their coating

3.2.3.4 Flared Connections

When flared connections are used, use a suitable lubricant between the back of the flare and the nut in order to avoid tearing the flare while tightening the nut.

3.2.3.5 Flanged Connections

When steel refrigerant piping is used, provide union or flange joints in each line immediately preceding the connection to each piece of equipment requiring maintenance, such as compressors, coils, chillers, control valves, and other similar items. Flanged joints must be assembled square end tight with matched flanges, gaskets, and bolts. Provide gaskets that are suitable for use with the refrigerants to be handled.

3.2.4 Valves

3.2.4.1 General

Install refrigerant stop valves on each side of each piece of equipment such as compressors condensers, evaporators, receivers, and other similar items in multiple-unit installation, to provide partial system isolation as required for maintenance or repair. Install stop valves with stems horizontal unless otherwise indicated. Install ball valves must be installed with stems positioned to facilitate operation and maintenance. Isolating valves for pressure gauges and switches must be external to thermal insulation. Safety switches must not be fitted with isolation valves. Filter dryers having access ports may be considered a point of isolation. Purge valves must be provided at all points of systems where accumulated non-condensable gases would prevent proper system operation. Valves must be furnished to match line size, unless otherwise indicated or approved.

3.2.4.2 Expansion Valves

Install expansion valves with the thermostatic expansion valve bulb located on top of the suction line when the suction line is less than 2-1/8 inches in diameter and at the 4 o'clock or 8 o'clock position on

lines larger than 2-1/8 inches. Fasten the bulb securely with two clamps. Insulate the bulb. Install the bulb in a horizontal portion of the suction line, if possible, with the pigtail on the bottom. If the bulb must be installed in a vertical line, the bulb tubing must be facing up.

3.2.4.3 Valve Identification

Tag each system valve, including those which are part of a factory assembly. Tags must be in alphanumeric sequence, progressing in direction of fluid flow. Tags must be embossed, engraved, or stamped plastic or nonferrous metal of various shapes, sized approximately 1-3/8 inch diameter, or equivalent dimension, substantially attached to a component or immediately adjacent thereto. Attach tags with nonferrous, heavy duty, bead or link chain, 14 gauge annealed wire, nylon cable bands or as approved. Reference tag numbers in Operation and Maintenance Manuals and system diagrams.

3.2.5 Vibration Dampers

Provide vibration damper in the suction and discharge lines on spring mounted compressors. Install vibration dampers parallel with the shaft of the compressor and anchor firmly at the upstream end on the suction line and the downstream end in the discharge line.

3.2.6 Strainers

Provide strainers immediately ahead of solenoid valves and expansion devices. Strainers may be an integral part of an expansion valve.

3.2.7 Filter Dryer

Provide a liquid line filter dryer on each refrigerant circuit located such that all liquid refrigerant passes through a filter dryer. Size dryers in accordance with the manufacturer's recommendations for the system in which it is installed. Install dryers such that it can be isolated from the system, the isolated portion of the system evacuated, and the filter dryer replaced. Install dryers in the horizontal position except replaceable core filter dryers may be installed in the vertical position with the access flange on the bottom.

3.2.8 Sight Glass

Install a moisture indicating sight glass in all refrigerant circuits downstream of all filter dryers and where indicated. Provide full line size sight glasses.

3.2.9 Discharge Line Oil Separator

Provide discharge line oil separator in the discharge line from each compressor. Connect the oil return line to the compressor as recommended by the compressor manufacturer.

3.2.10 Accumulator

Provide accumulators in the suction line to each compressor.

3.2.11 Flexible Pipe Connectors

Install connectors perpendicular to line of motion being isolated. Fit piping for equipment with bidirectional motion with two flexible connectors, in perpendicular planes. Install reinforced elastomer flexible connectors in accordance with manufacturer's instructions. Provide piping guides and restraints related to flexible connectors as required.

3.2.12 Temperature Gauges

Locate temperature gauges specifically on, but not limited to the following: the sensing element of each automatic temperature control device where a thermometer is not an integral part thereof the liquid line leaving a receiver and the suction line at each evaporator or liquid cooler. Thermowells for insertion thermometers and thermostats must extend beyond thermal insulation surface not less than 1 inch.

3.2.13 Pipe Hangers, Inserts, and Supports

Pipe hangers, inserts, and supports must conform to MSS SP-58, except as modified herein. Do not use pipe hanger types 5, 12, and 26. Fabricate hangers used to support piping 2 inches and larger to permit adequate adjustment after erection while still supporting the load. Support piping subjected to vertical movement, when operating temperatures exceed ambient temperatures, by variable spring hangers and supports or by constant support hangers.

3.2.13.1 Hangers

Do not use Type 3 on insulated piping. Type 24 may be used only on trapeze hanger systems or on fabricated frames.

3.2.13.2 Inserts

Secure Type 18 inserts to concrete forms before concrete is placed. Continuous inserts which allow more adjustments may be used if they otherwise meet the requirements for Type 18 inserts.

3.2.13.3 C-Clamps

Torque Type 19 and 23 C-clamps in accordance with MSS SP-58 and have both locknuts and retaining devices, furnished by the manufacturer. Field-fabricated C-clamp bodies or retaining devices are not acceptable.

3.2.13.4 Angle Attachments

Furnish Type 20 attachments used on angles and channels with an added malleable-iron heel plate or adapter.

3.2.13.5 Saddles and Shields

Where Type 39 saddle or Type 40 shield are permitted for a particular pipe attachment application, the Type 39 saddle, connected to the pipe, must be used on all pipe 4 inches and larger when the temperature of the medium is 60 degrees F or higher. Use Type 40 shields on all piping less than 4 inches and all piping 4 inches and larger carrying medium less than 60 degrees F. Use a high-density insulation insert of cellular glass under the Type 40 shield for piping 2 inches and larger.

3.2.13.6 Horizontal Pipe Supports

Space horizontal pipe supports as specified in MSS SP-58 and install a support no more than 1 foot from the pipe fitting joint at each change in direction of the piping. Space pipe supports no more than 5 feet apart at valves. Pipe hanger loads suspended from steel joist with hanger loads between panel points in excess of 50 pounds must have the excess hanger loads suspended from panel points.

3.2.13.7 Vertical Pipe Supports

Support vertical pipe at each floor, except at slab-on-grade, and at intervals of not more than 15 feet not more than 8 feet from end of risers, and at vent terminations.

3.2.13.8 Pipe Guides

Provide Type 35 guides using, steel, reinforced polytetrafluoroethylene (PTFE) or graphite slides where required to allow longitudinal pipe movement. Provide lateral restraints as required. Provide slide materials that are suitable for the system operating temperatures, atmospheric conditions, and bearing loads encountered.

3.2.13.9 Steel Slides

Where steel slides do not require provisions for restraint of lateral movement, an alternate guide method may be used. On piping 4 inches and larger, use a Type 39 saddle. On piping under 4 inches, a Type 40 protection shield may be attached to the pipe or insulation and freely rest on a steel slide plate.

3.2.13.10 High Temperature Guides with Cradles

Where there are high system temperatures and welding to piping is not desirable, the Type 35 guide must include a pipe cradle, welded to the guide structure and strapped securely to the pipe. Separate the pipe from the slide material by at least 4 inches, or by an amount adequate for the insulation, whichever is greater.

3.2.13.11 Multiple Pipe Runs

In the support of multiple pipe runs on a common base member, use a clip or clamp where each pipe crosses the base support member. Spacing of the base support members must not exceed the hanger and support spacing required for an individual pipe in the multiple pipe run.

3.2.13.12 Seismic Requirements

Support and brace piping and attached valves to resist seismic loads as specified under UFC 3-301-01. Provide structural steel required for reinforcement to properly support piping, headers, and equipment but not shown under this section. Specify material used for support under Section 05 12 00 STRUCTURAL STEEL.

3.2.13.13 Structural Attachments

Attachment to building structure concrete and masonry must be by cast-in concrete inserts, built-in anchors, or masonry anchor devices. Inserts

and anchors must be applied with a safety factor not less than 5. Do not attach supports to metal decking. Construct masonry anchors for overhead applications of ferrous materials only. Provide structural steel brackets required to support piping, headers, and equipment, but not shown, under this section. Specify material used for support under Section 05 12 00 STRUCTURAL STEEL.

3.2.14 Pipe Alignment Guides

Provide pipe alignment guides where indicated for expansion loops, offsets, and bends and as recommended by the manufacturer for expansion joints, not to exceed 5 feet on each side of each expansion joint, and in lines 4 inches or smaller not more than 2 feet on each side of the joint.

3.2.15 Pipe Anchors

Provide anchors wherever necessary or indicated to localize expansion or to prevent undue strain on piping. Provide anchors consisting of heavy steel collars with lugs and bolts for clamping and attaching anchor braces, unless otherwise indicated. Install anchor braces in the most effective manner to secure the desired results using turnbuckles where required. Do not attach supports, anchors, or stays where they will injure the structure or adjacent construction during installation or by the weight of expansion of the pipeline. Where pipe and conduit penetrations of vapor barrier sealed surfaces occur, immediately anchor these items adjacent to each penetrated surface, to provide essentially zero movement within penetration seal. Submit detailed drawings of pipe anchors for approval before installation.

3.2.16 Building Surface Penetrations

Do not install sleeves in structural members except where indicated or approved. Provide galvanized sheet metal sleeves in non-load bearing surfaces conforming to ASTM A653/A653M, Coating Class G-90, 20 gauge. Provide uncoated carbon steel pipe sleeves in load bearing surfaces conforming to ASTM A53/A53M, Standard weight. Apply sealants to moisture and oil-free surfaces and elastomers to not less than 1/2 inch depth. Do not install sleeves in structural members.

3.2.16.1 Refrigerated Space

Fit refrigerated space building surface penetrations with sleeves fabricated from hand-lay-up or helically wound, fibrous glass reinforced polyester or epoxy resin with a minimum thickness equal to equivalent size Schedule 40 steel pipe. Construct sleeves with integral collar or fit cold side with a bonded slip-on flange or extended collar. In the case of masonry penetrations where sleeve is not cast-in, fill voids with latex mixed mortar cast to shape of sleeve and assemble flange/external collar type sleeve with butyl elastomer vapor barrier sealant through penetration to cold side surface vapor barrier overlap and fastened to surface with masonry anchors. Flash integral cast-in collar type sleeve with not less than 4 inches of cold side vapor barrier overlap of sleeve surface. Normally seal noninsulated penetrating round surfaces to sleeve bore with mechanically expandable seals in vapor tight manner and insulate remaining warm and cold side sleeve depth with not less than 4 inches of foamed-in-place rigid polyurethane or foamed-in-place silicone elastomer. Apply vapor barrier sealant to finish warm side insulation surface. Insulate warm side of penetrating surface beyond vapor barrier sealed sleeve insulation for a distance which prevents condensation. Seal wires

in refrigerated space surface penetrating conduit with vapor barrier plugs or compound to prevent moisture migration through conduit and condensation therein.

3.2.16.2 General Service Areas

Extend each sleeve through its respective wall, floor, or roof, and cut flush with each surface. Provide pipes passing through concrete or masonry wall or concrete floors or roofs with pipe sleeves fitted into place at the time of construction. Provide sleeves that allow a minimum of 1/4 inch all-around clearance between bare pipe and sleeves or between jacketed-insulation and sleeves. Except in pipe chases or interior walls, seal the annular space between pipe and sleeve or between jacket over-insulation and sleeve in accordance with Section 07 92 00 JOINT SEALANTS.

3.2.16.3 Waterproof Penetrations

Install pipes passing through roof or floor waterproofing membrane through a 17 ounce copper sleeve, or a 0.032 inch thick aluminum sleeve, each within an integral skirt or flange. Form flashing sleeve, and extend skirt or flange greater than 8 inches from the pipe and set over the roof or floor membrane in a troweled coating of bituminous cement. Extend the flashing sleeve up the pipe a minimum of 2 inches above the roof or floor penetration. Seal the annular space between the flashing sleeve and the bare pipe or between the flashing sleeve and the metal-jacket-covered insulation as indicated. Seal penetrations by either one of the following methods.

3.2.16.3.1 Waterproofing Clamping Flange

Pipes up to and including 10 inches in diameter passing through roof or floor waterproofing membrane may be installed through a cast iron sleeve with caulking recess, anchor lugs, flashing clamp device, and pressure ring with brass bolts. Clamp waterproofing membrane into place and place sealant in the caulking recess.

3.2.16.3.2 Modular Mechanical Type Sealing Assembly

In lieu of a waterproofing clamping flange and caulking and sealing of annular space between pipe and sleeve or conduit and sleeve, a modular mechanical type sealing assembly may be installed. Provide seals consisting of interlocking synthetic rubber links shaped to continuously fill the annular space between the pipe/conduit and sleeve with corrosion protected carbon steel bolts, nuts, and pressure plates. Loosely assemble links with bolts to form a continuous rubber belt around the pipe with a pressure plate under each bolt head and each nut. After the seal assembly is properly positioned in the sleeve, tighten the bolt to cause the rubber sealing elements to expand and provide a watertight seal between the pipe/conduit and the sleeve. Size each seal assembly as recommended by the manufacturer to fit the pipe/conduit and sleeve involved. The Contractor electing to use the modular mechanical type seals must provide sleeves of the proper diameters.

3.2.16.4 Fire-Rated Penetrations

Seal penetration of fire-rated walls, partitions, and floors as specified in Section 07 84 00 FIRESTOPPING.

3.2.16.5 Escutcheons

Provide escutcheons for finished surfaces where exposed piping, bare or insulated, pass through floors, walls, or ceilings, except in boiler, utility, or equipment rooms. Where sleeves project slightly from floors, use special deep-type escutcheons. Secure escutcheon to pipe or pipe covering.

3.2.17 Access Panels

Provide access panels for all concealed valves, vents, controls, and items requiring inspection or maintenance. Provide access panels of sufficient size and locate so that the concealed items may be serviced and maintained or completely removed and replaced. Provide access panels as specified in Section 08 31 00 ACCESS DOORS AND PANELS.

3.2.18 Field Applied Insulation

Field installed insulation is specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS, except as defined differently herein.

3.2.19 Field Painting

Painting required for surfaces not otherwise specified, and finish painting of items only primed at the factory are specified in Section 09 90 00 PAINTS AND COATINGS.

3.2.19.1 Color Coding

Color coding for piping identification is specified in Section 09 90 00 PAINTS AND COATINGS.

3.2.19.2 Color Coding Scheme

Provide a color coding scheme for locating hidden piping in accordance with Section 22 00 00 PLUMBING, GENERAL PURPOSE.

3.2.20 Identification Tags

Provide identification tags made of brass, engraved laminated plastic or engraved anodized aluminum indicating service and item number on all valves and dampers. Tags must be 1-3/8 inch minimum diameter and marking must be stamped or engraved. Indentations must be black for reading clarity. Attach tags to valves with No. 12 AWG copper wire, chrome-plated beaded chain or plastic straps designed for that purpose.

3.3 CLEANING AND ADJUSTING

Clean uncontaminated system(s) by evacuation and purging procedures currently recommended by refrigerant and refrigerant equipment manufacturers, and as specified herein, to remove small amounts of air and moisture. Systems containing moderate amounts of air, moisture, contaminated refrigerant, or any foreign matter are considered contaminated systems. Restore contaminated systems to clean condition including disassembly, component replacement, evacuation, flushing, purging, and re-charging, using currently approved refrigerant and refrigeration manufacturer's procedures. Restore contaminated systems at no additional cost to the Government as determined by the Contracting Officer. Do not use water in any procedure or test.

3.4 TRAINING COURSE

- a. Submit a schedule, at least 2 weeks prior to the date of the proposed training course, which identifies the date, time, and location for the training. Conduct a training course for members of the operating staff as designated by the Contracting Officer. The training period must consist of a total 4 hours of normal working time and start after the system is functionally completed but prior to final acceptance tests.
- b. Cover all of the items contained in the approved operation and maintenance manuals as well as demonstrations of routine maintenance operations in the field posted instructions..
- c. Submit 6 complete copies of an operation manual in bound 8 1/2 by 11 inch booklets listing step-by-step procedures required for system startup, operation, abnormal shutdown, emergency shutdown, and normal shutdown at least 4 weeks prior to the first training course. Include the manufacturer's name, model number, and parts list in the booklets. Include the manufacturer's name, model number, service manual, and a brief description of all equipment and their basic operating features in the manuals.
- d. Submit 6 complete copies of maintenance manual in bound 8 1/2 x 11 inch booklets listing routine maintenance procedures, possible breakdowns and repairs, and a trouble shooting guide. Include piping layouts and simplified wiring and control diagrams of the system as installed in the manuals.

3.5 REFRIGERANT PIPING TESTS

After all components of the refrigerant system have been installed and connected, subject the entire refrigeration system to pneumatic, evacuation, and startup tests as described herein. Submit a schedule, at least 2 weeks prior to the start of related testing, for each test. Identify the proposed date, time, and location for each test. Conduct tests in the presence of the Contracting Officer. Water and electricity required for the tests will be furnished by the Government. Provide all material, equipment, instruments, and personnel required for the test. Provide the services of a qualified technician, as required, to perform all tests and procedures indicated herein. Coordinate field tests with Section 23 05 93 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS. Submit 6 copies of the tests report in bound 8 1/2 by 11 inch booklets documenting all phases of the tests performed. Include initial test summaries, all repairs/adjustments made, and the final test results in the report.

3.5.1 Preliminary Procedures

Prior to pneumatic testing, isolate equipment which has been factory tested and refrigerant charged as well as equipment which could be damaged or cause personnel injury by imposed test pressure, positive or negative, from the test pressure, or remove from the system. Remove safety relief valves and rupture discs that are not part of factory sealed systems, and cap or plug openings.

3.5.2 Pneumatic Test

Provide pressure control and excess pressure protection at the source of test pressure. Valves must be wide open, except those leading to the atmosphere. Test gas must be dry nitrogen, with minus 70 degree F dewpoint and less than 5 ppm oil. Apply test pressure in two stages before any refrigerant pipe is insulated or covered. In accordance with ASME B31.5, a preliminary test not to exceed 25 psi must be applied as a means of locating major leaks. Every joint being tested must be coated with a thick soap or color indicating solution. The second stage test pressure must be at least 110 percent of the design pressure, but cannot exceed 130 percent of the design pressure of any component in the system. For large systems that are not completely visible, the pressure in the system must be gradually increased to one-half of the test pressure after which the pressure must be increased in steps of one-tenth of the test pressure, until the required test pressure has been reached. The test pressure must be continuously maintained for at least 24 hours, after which it can be reduced to the leak test pressure. A correction factor of 0.3 psi will be allowed for each degree F change between test space initial and final ambient temperature, plus for increase and minus for a decrease. The leak test pressure must be the design pressure, or a pressure specified in the engineering design. To repair leaks, the joint must be taken apart, thoroughly cleaned, and reconstructed as a new joint. Joints repaired by caulking, re-melting, or back-welding/brazing are not acceptable. Following repair, the entire system must be retested using the pneumatic tests described above. Reassemble the entire system once the pneumatic tests are satisfactorily completed.

3.5.3 Evacuation Test

Following satisfactory completion of the pneumatic tests, relieve the pressure and evacuate the entire system to an absolute pressure of 300 micrometers. During evacuation of the system, the ambient temperature must be higher than 35 degrees F. Do not evacuate no more than one system at one time by one vacuum pump. Once the desired vacuum has been reached, close the vacuum line and allow the system to stand for 1 hour. If the pressure rises over 500 micrometers after the 1 hour period, evacuate the system again down to 300 micrometers and let set for another 1 hour period. Do not charge the system until a vacuum of at least 500 micrometers is maintained for a period of 1 hour without the assistance of a vacuum line. If during the testing the pressure rises above 500 micrometers, continue to repeat the evacuation procedures until all residual moisture has been removed. During evacuation, record pressures by a thermocouple-type, electronic-type, or a calibrated-micrometer type gauge.

3.5.4 System Charging and Startup Test

Following satisfactory completion of the evacuation tests, charge the system with the required amount of refrigerant by raising pressure to normal operating pressure and in accordance with manufacturer's procedures. Following charging, the system must operate with high-side and low-side pressures and corresponding refrigerant temperatures, at design or improved values. Test the entire system tested for leaks. Test fluorocarbon systems with halide torch or electronic leak detectors.

3.5.5 Refrigerant Leakage

If a refrigerant leak is discovered after the system has been charged, the

leaking portion of the system must be immediately isolated from the remainder of the system and the refrigerant pumped into the system receiver or other suitable container. The refrigerant must not be discharged into the atmosphere.

3.5.6 Contractor's Responsibility

At all times during the installation and testing of the refrigeration system, take steps to prevent the release of refrigerants into the atmosphere. The steps must include, but not be limited to, procedures which will minimize the release of refrigerants to the atmosphere and the use of refrigerant recovery devices to remove refrigerant from the system and store the refrigerant for reuse or reclaim. At no time will the allowable leak rate exceed the leak rates allowed in Section 608 of the Clean Air Act: 30 percent of the full charge per year for industrial refrigeration, 20 percent of the full charge per year for commercial refrigeration, and 10 percent of the full charge per year for comfort cooling. Any system leaks within the first year must be repaired in accordance with the requirements herein at no cost to the Government including material, labor, and refrigerant if the leak is the result of defective equipment, material, or installation.

-- End of Section --

SECTION 23 30 00

HVAC AIR DISTRIBUTION
05/20, CHG 1: 02/22

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ACOUSTICAL SOCIETY OF AMERICA (ASA)

ASA S12.51 (2012; R 2017) American National Standard Acoustics - Determination of Sound Power Levels and Sound Energy Levels of Noise Sources using Sound Pressure - Precision Methods for Reverberation Test Rooms

AIR CONDITIONING CONTRACTORS OF AMERICA (ACCA)

ACCA Manual 4 (2001) Installation Techniques for Perimeter Heating and Cooling; 11th Edition

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC. (AMCA)

AMCA 201 (2002; R 2011) Fans and Systems
AMCA 210 (2016) Laboratory Methods of Testing Fans for Aerodynamic Performance Rating
AMCA 220 (2005;R 2012) Test Methods for Air Curtain Units
AMCA 300 (2014) Reverberant Room Method for Sound Testing of Fans
AMCA 301 (2014) Methods for Calculating Fan Sound Ratings from Laboratory Test Data
AMCA 500-D (2018) Laboratory Methods of Testing Dampers for Rating

AIR-CONDITIONING, HEATING AND REFRIGERATION INSTITUTE (AHRI)

AHRI 260 I-P (2012) Sound Rating of Ducted Air Moving and Conditioning Equipment
AHRI 350 (2015) Sound Rating of Non-Ducted Indoor Air-Conditioning Equipment
AHRI 410 (2001; Addendum 1 2002; Addendum 2 2005; Addendum 3 2011) Forced-Circulation Air-Cooling and Air-Heating Coils
AHRI 430 (2009) Central-Station Air-Handling Units

AHRI 440 (2008) Performance Rating of Room Fan-Coils
AHRI 880 I-P (2011) Performance Rating of Air Terminals
AHRI 885 (2008; Addendum 2011) Procedure for
Estimating Occupied Space Sound Levels in
the Application of Air Terminals and Air
Outlets
AHRI Guideline D (1996) Application and Installation of
Central Station Air-Handling Units

AMERICAN BEARING MANUFACTURERS ASSOCIATION (ABMA)

ABMA 9 (2015) Load Ratings and Fatigue Life for
Ball Bearings
ABMA 11 (2014) Load Ratings and Fatigue Life for
Roller Bearings

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING
ENGINEERS (ASHRAE)

ASHRAE 52.2 (2012) Method of Testing General
Ventilation Air-Cleaning Devices for
Removal Efficiency by Particle Size
ASHRAE 62.1 (2016) Ventilation for Acceptable Indoor
Air Quality
ASHRAE 68 (1997) Laboratory Method of Testing to
Determine the Sound Power In a Duct
ASHRAE 70 (2006; R 2021) Method of Testing the
Performance of Air Outlets and Inlets
ASHRAE 84 (2020; Errata 2021) Method of Testing
Air-to-Air Heat/Energy Exchangers
ASHRAE 90.1 - IP (2019) Energy Standard for Buildings
Except Low-Rise Residential Buildings

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME A13.1 (2020) Scheme for the Identification of
Piping Systems

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M (2024) Standard Specification for Pipe,
Steel, Black and Hot-Dipped, Zinc-Coated,
Welded and Seamless
ASTM A123/A123M (2017) Standard Specification for Zinc
(Hot-Dip Galvanized) Coatings on Iron and
Steel Products
ASTM A167 (2011) Standard Specification for

	Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
ASTM A924/A924M	(2022a) Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process
ASTM B117	(2019) Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM B152/B152M	(2019) Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar
ASTM B209	(2014) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B280	(2020) Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
ASTM B766	(1986; R 2015) Standard Specification for Electrodeposited Coatings of Cadmium
ASTM C553	(2013; R 2019) Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
ASTM C916	(2020) Standard Specification for Adhesives for Duct Thermal Insulation
ASTM C1071	(2019) Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)
ASTM D520	(2000; R 2011) Zinc Dust Pigment
ASTM D1654	(2008; R 2016; E 2017) Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
ASTM D1785	(2015; E 2018) Standard Specification for Poly(Vinyl Chloride) (PVC), Plastic Pipe, Schedules 40, 80, and 120
ASTM D2466	(2017) Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
ASTM D2564	(2020) Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems
ASTM D2855	(2015) Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings
ASTM D3359	(2017) Standard Test Methods for Rating

Adhesion by Tape Test

ASTM E84 (2023) Standard Test Method for Surface Burning Characteristics of Building Materials

ASTM E2016 (2022) Standard Specification for Industrial Woven Wire Cloth

CALIFORNIA DEPARTMENT OF PUBLIC HEALTH (CDPH)

CDPH SECTION 01350 (2017; Version 1.2) Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources using Environmental Chambers

INSTITUTE OF ENVIRONMENTAL SCIENCES AND TECHNOLOGY (IEST)

IEST RP-CC-001 (2016; Rev 6) HEPA and ULPA Filters

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA MG 1 (2021) Motors and Generators

NEMA MG 10 (2017) Energy Management Guide for Selection and Use of Fixed Frequency Medium AC Squirrel-Cage Polyphase Induction Motors

NEMA MG 11 (1977; R 2012) Energy Management Guide for Selection and Use of Single Phase Motors

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 90A (2024) Standard for the Installation of Air Conditioning and Ventilating Systems

NFPA 96 (2024) Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations

NFPA 701 (2023; ERTA 1 2023) Standard Methods of Fire Tests for Flame Propagation of Textiles and Films

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)

SMACNA 1819 (2002) Fire, Smoke and Radiation Damper Installation Guide for HVAC Systems, 5th Edition

SMACNA 1966 (2020) HVAC Duct Construction Standards Metal and Flexible, 4th Edition

SMACNA 1972 CD (2012) HVAC Air Duct Leakage Test Manual - 2nd Edition

SMACNA 1981 (2008) Seismic Restraint Manual Guidelines

for Mechanical Systems, 3rd Edition

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT (SCAQMD)

SCAQMD Rule 1168 (2017) Adhesive and Sealant Applications

U.S. DEPARTMENT OF ENERGY FEDERAL ENERGY MANAGEMENT PROGRAM (FEMP)

PL-109-58 (1992; R 2005) Energy Efficient Procurement Requirements

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

40 CFR 82 Protection of Stratospheric Ozone

UNDERWRITERS LABORATORIES (UL)

UL 6 (2022) UL Standard for Safety Electrical Rigid Metal Conduit-Steel

UL 94 (2023; Reprint Jan 2024) UL Standard for Safety Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 181 (2013; Reprint Dec 2021) UL Standard for Safety Factory-Made Air Ducts and Air Connectors

UL 555 (2006; Reprint Aug 2016) UL Standard for Safety Fire Dampers

UL 586 (2009; Reprint Sep 2022) UL Standard for Safety High-Efficiency Particulate, Air Filter Units

UL 705 (2017; Reprint Aug 2022) UL Standard for Safety Power Ventilators

UL 723 (2020) UL Standard for Safety Test for Surface Burning Characteristics of Building Materials

UL 900 (2015; Reprint Aug 2022) UL Standard for Safety Standard for Air Filter Units

UL 1995 (2015; Reprint Aug 2022) UL Standard for Safety Heating and Cooling Equipment

UL Bld Mat Dir (updated continuously online) Building Materials Directory

UL Electrical Construction (2012) Electrical Construction Equipment Directory

UL Fire Resistance (2014) Fire Resistance Directory

1.2 SYSTEM DESCRIPTION

Furnish ductwork, piping offsets, fittings, and accessories as required to provide a complete installation. Coordinate the work of the different trades to avoid interference between piping, equipment, structural, and electrical work. Provide complete, in place, all necessary offsets in piping and ductwork, and all fittings, and other components, required to install the work as indicated and specified.

1.2.1 Mechanical Equipment Identification

The number of charts and diagrams must be equal to or greater than the number of mechanical equipment rooms. Where more than one chart or diagram per space is required, mount these in edge pivoted, swinging leaf, extruded aluminum frame holders which open to 170 degrees.

1.2.1.1 Charts

Provide chart listing of equipment by designation numbers and capacities such as flow rates, pressure and temperature differences, heating and cooling capacities, horsepower, pipe sizes, and voltage and current characteristics.

1.2.1.2 Diagrams

Submit proposed diagrams, at least 2 weeks prior to start of related testing. provide neat mechanical drawings provided with extruded aluminum frame under 1/8-inch glass or laminated plastic, system diagrams that show the layout of equipment, piping, and ductwork, and typed condensed operation manuals explaining preventative maintenance procedures, methods of checking the system for normal, safe operation, and procedures for safely starting and stopping the system. After approval, post these items where directed.

1.2.2 Service Labeling

Label equipment, including fans, air handlers, terminal units, etc. with labels made of self-sticking, plastic film designed for permanent installation. Provide labels in accordance with the typical examples below:

SERVICE	LABEL AND TAG DESIGNATION
Air handling unit Number	AHU -
Control and instrument air	CONTROL AND INSTR.
Exhaust Fan Number	EF -
VAV Box Number	VAV -
Fan Coil Unit Number	FC -
Terminal Box Number	TB -

SERVICE	LABEL AND TAG DESIGNATION
Unit Ventilator Number	UV -

Identify similar services with different temperatures or pressures. Where pressures could exceed 125 pounds per square inch, gage, include the maximum system pressure in the label. Label and arrow piping in accordance with the following:

- a. Each point of entry and exit of pipe passing through walls.
- b. Each change in direction, i.e., elbows, tees.
- c. In congested or hidden areas and at all access panels at each point required to clarify service or indicated hazard.
- d. In long straight runs, locate labels at distances within eyesight of each other not to exceed 75 feet. All labels must be visible and legible from the primary service and operating area.

For Bare or Insulated Pipes	
for Outside Diameters of	Lettering
1/2 thru 1-3/8 inch	1/2 inch
1-1/2 thru 2-3/8 inch	3/4 inch
2-1/2 inch and larger	1-1/4 inch

1.2.3 Color Coding

Color coding of all piping systems must be in accordance with ASME A13.1 .

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Detail Drawings; G

SD-03 Product Data

Metallic Flexible Duct

Insulated Nonmetallic Flexible Duct Runouts

Duct Connectors

Duct Access Doors; G

Fire Dampers

Manual Balancing Dampers; G

Sound Attenuation Equipment

Acoustical Duct Liner

Diffusers

Registers and Grilles

Louvers

Air Vents, Penthouses, and Goosenecks

Centrifugal Fans

In-Line Centrifugal Fans

Axial Flow Fans

Panel Type Power Wall Ventilators

Centrifugal Type Power Wall Ventilators

Centrifugal Type Power Roof Ventilators

Propeller Type Power Roof Ventilators

Air-Curtain Fans

Ceiling Exhaust Fans

PL-109-58 label for ceiling exhaust fan product; S

Air Handling Units; G

Room Fan-Coil Units; G

Coil Induction Units; G

Variable Volume, Single Duct Terminal Units; G

Dual Duct Terminal Units; G

Ceiling Induction Terminal Units; G

Unit Ventilators

Energy Recovery Devices; G

Test Procedures

Diagrams; G

Indoor Air Quality for Duct Sealants; S

SD-06 Test Reports

Performance Tests; G

Damper Acceptance Test; G

SD-07 Certificates

Bolts

Ozone Depleting Substances Technician Certification

SD-08 Manufacturer's Instructions

Manufacturer's Installation Instructions

Operation and Maintenance Training

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G

Fire Dampers; G

Manual Balancing Dampers; G

Centrifugal Fans; G

In-Line Centrifugal Fans; G

Axial Flow Fans; G

Panel Type Power Wall Ventilators; G

Centrifugal Type Power Wall Ventilators; G

Centrifugal Type Power Roof Ventilators; G

Propeller Type Power Roof Ventilators; G

Air-Curtain Fans; G

Ceiling Exhaust Fans; G

Air Handling Units; G

Room Fan-Coil Units; G

Coil Induction Units; G

Variable Volume, Single Duct Terminal Units; G

Dual Duct Terminal Units; G

Ceiling Induction Terminal Units; G

Unit Ventilators; G

Energy Recovery Devices; G

SD-11 Closeout Submittals

Indoor Air Quality During Construction; S

1.4 QUALITY ASSURANCE

Except as otherwise specified, approval of materials and equipment is based on manufacturer's published data.

- a. Where materials and equipment are specified to conform to the standards of the Underwriters Laboratories, the label of or listing with reexamination in UL Bld Mat Dir, and UL 6 is acceptable as sufficient evidence that the items conform to Underwriters Laboratories requirements. In lieu of such label or listing, submit a written certificate from any nationally recognized testing agency, adequately equipped and competent to perform such services, stating that the items have been tested and that the units conform to the specified requirements. Outline methods of testing used by the specified agencies.
- b. Where materials or equipment are specified to be constructed or tested, or both, in accordance with the standards of the ASTM International (ASTM), the ASME International (ASME), or other standards, a manufacturer's certificate of compliance of each item is acceptable as proof of compliance.
- c. Conformance to such agency requirements does not relieve the item from compliance with other requirements of these specifications.
- d. Where products are specified to meet or exceed the specified energy efficiency requirement of FEMP-designated or ENERGY STAR covered product categories, equipment selected must have as a minimum the efficiency rating identified under "Energy-Efficient Products" at <http://femp.energy.gov/procurement>.

1.4.1 Prevention of Corrosion

Protect metallic materials against corrosion. Provide rust-inhibiting treatment and standard finish for the equipment enclosures. Do not use aluminum in contact with earth, and where connected to dissimilar metal. Protect aluminum by approved fittings, barrier material, or treatment. Provide hot-dip galvanized ferrous parts such as anchors, bolts, braces, boxes, bodies, clamps, fittings, guards, nuts, pins, rods, shims, thimbles, washers, and miscellaneous parts not of corrosion-resistant steel or nonferrous materials in accordance with ASTM A123/A123M for exterior locations and cadmium-plated in conformance with ASTM B766 for interior locations.

1.4.2 Asbestos Prohibition

Do not use asbestos and asbestos-containing products.

1.4.3 Ozone Depleting Substances Technician Certification

All technicians working on equipment that contain ozone depleting refrigerants must be certified as a Section 608 Technician to meet requirements in 40 CFR 82, Subpart F. Provide copies of technician certifications to the Contracting Officer at least 14 calendar days prior to work on any equipment containing these refrigerants.

1.4.4 Detail Drawings

Submit detail drawings showing equipment layout, including assembly and installation details and electrical connection diagrams; ductwork layout showing the location of all supports and hangers, typical hanger details, gauge reinforcement, reinforcement spacing rigidity classification, and static pressure and seal classifications. Include any information required to demonstrate that the system has been coordinated and functions properly as a unit on the drawings and show equipment relationship to other parts of the work, including clearances required for operation and maintenance. Submit drawings showing bolt-setting information, and foundation bolts prior to concrete foundation construction for all equipment indicated or required to have concrete foundations. Submit function designation of the equipment and any other requirements specified throughout this Section with the shop drawings.

1.4.5 Test Procedures

Conduct performance tests as required in Section 23 05 93 Testing, Adjusting and Balancing for HVAC and Section 23 09 00 Instrumentation and Control for HVAC.

1.5 DELIVERY, STORAGE, AND HANDLING

Protect stored equipment at the jobsite from the weather, humidity and temperature variations, dirt and dust, or other contaminants. Additionally, cap or plug all pipes until installed.

PART 2 PRODUCTS

2.1 STANDARD PRODUCTS

Provide components and equipment that are "standard products" of a manufacturer regularly engaged in the manufacturing of products that are of a similar material, design and workmanship. "Standard products" is defined as being in satisfactory commercial or industrial use for 2 years before bid opening, including applications of components and equipment under similar circumstances and of similar size, satisfactorily completed by a product that is sold on the commercial market through advertisements, manufacturers' catalogs, or brochures. Products having less than a 2-year field service record are acceptable if a certified record of satisfactory field operation, for not less than 6000 hours exclusive of the manufacturer's factory tests, can be shown. Provide equipment items that are supported by a service organization. In product categories covered by ENERGY STAR or the Federal Energy Management Program, provide equipment that is listed on the ENERGY STAR Qualified Products List or that meets or exceeds the FEMP-designated Efficiency Requirements.

2.2 IDENTIFICATION PLATES

In addition to standard manufacturer's identification plates, provide engraved laminated phenolic identification plates for each piece of mechanical equipment. Identification plates are to designate the function of the equipment. Submit designation with the shop drawings. Provide identification plates that are layers, black-white-black, engraved to show white letters on black background. Letters must be upper case. Identification plates that are 1-1/2-inches high and smaller must be 1/16-inch thick, with engraved lettering 1/8-inch high; identification plates larger than 1-1/2-inches high must be 1/8-inch thick, with engraved lettering of suitable height. Identification plates 1-1/2-inches high and larger must have beveled edges. Install identification plates using a compatible adhesive.

2.3 EQUIPMENT GUARDS AND ACCESS

Fully enclose or guard belts, pulleys, chains, gears, couplings, projecting setscrews, keys, and other rotating parts exposed to personnel contact according to OSHA requirements. Properly guard or cover with insulation of a type specified, high temperature equipment and piping exposed to contact by personnel or where it creates a potential fire hazard. The requirements for catwalks, operating platforms, ladders, and guardrails are specified in Section 08 31 00 ACCESS DOORS AND PANELS.

2.4 ELECTRICAL WORK

- a. Provide motors, controllers, integral disconnects, contactors, and controls with their respective pieces of equipment, except controllers indicated as part of motor control centers. Provide electrical equipment, including motors and wiring, as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide manual or automatic control and protective or signal devices required for the operation specified and control wiring required for controls and devices specified, but not shown. For packaged equipment, include manufacturer provided controllers with the required monitors and timed restart.
- b. For single-phase motors, provide high-efficiency type, fractional-horsepower alternating-current motors, including motors that are part of a system, in accordance with NEMA MG 11. Provide premium efficiency type integral size motors in accordance with NEMA MG 1.
- c. For polyphase motors, provide squirrel-cage medium induction motors, including motors that are part of a system, and that meet the efficiency ratings for premium efficiency motors in accordance with NEMA MG 1. Select premium efficiency polyphase motors in accordance with NEMA MG 10.
- d. Provide motors in accordance with NEMA MG 1 and of sufficient size to drive the load at the specified capacity without exceeding the nameplate rating of the motor. Provide motors rated for continuous duty with the enclosure specified. Provide motor duty that allows for maximum frequency start-stop operation and minimum encountered interval between start and stop. Provide motor torque capable of accelerating the connected load within 20 seconds with 80 percent of the rated voltage maintained at motor terminals during one starting

period. Provide motor starters complete with thermal overload protection and other necessary appurtenances. Fit motor bearings with grease supply fittings and grease relief to outside of the enclosure.

- e. Where two-speed or variable-speed motors are indicated, solid-state variable-speed controllers are allowed to accomplish the same function. Use solid-state variable-speed controllers for motors rated 10 hp or less and adjustable frequency drives for larger motors. Provide variable frequency drives for motors as specified in Section 26 29 23 ADJUSTABLE SPEED DRIVE SYSTEMS UNDER 600 VOLTS.

2.5 ANCHOR BOLTS

Provide anchor bolts for equipment placed on concrete equipment pads or on concrete slabs. Bolts to be of the size and number recommended by the equipment manufacturer and located by means of suitable templates. Installation of anchor bolts must not degrade the surrounding concrete.

2.6 SEISMIC ANCHORAGE

Anchor equipment in accordance with applicable seismic criteria for the area and as defined in SMACNA 1981

2.7 PAINTING

Paint equipment units in accordance with approved equipment manufacturer's standards unless specified otherwise. Field retouch only if approved. Otherwise, return equipment to the factory for refinishing.

2.8 INDOOR AIR QUALITY

Provide equipment and components that comply with the requirements of ASHRAE 62.1 unless more stringent requirements are specified herein.

2.9 DUCT SYSTEMS

2.9.1 Metal Ductwork

Provide metal ductwork construction, including all fittings and components, that complies with SMACNA 1966, as supplemented and modified by this specification .

- b. Provide radius type elbows with a centerline radius of 1.5 times the width or diameter of the duct where space permits. Otherwise, elbows having a minimum radius equal to the width or diameter of the duct or square elbows with factory fabricated turning vanes are allowed.
- c. Provide ductwork that meets the requirements of Seal Class C. Provide ductwork in VAV systems upstream of the VAV boxes that meets the requirements of Seal Class A.
- e. Provide sealants that conform to fire hazard classification specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS and are suitable for the range of air distribution and ambient temperatures to which it is exposed. Do not use pressure sensitive tape as a

sealant. Provide duct sealant products that meet either emissions requirements of CDPH SECTION 01350 (limit requirements for either office or classroom spaces regardless of space type) or VOC content requirements of SCAQMD Rule 1168 (HVAC duct sealants are classified as "Other" within the SCAQMD Rule 1168 sealants table). Provide validation of indoor air quality for duct sealants.

- f. Make spiral lock seam duct, and flat oval with duct sealant and lock with not less than 3 equally spaced drive screws or other approved methods indicated in SMACNA 1966. Apply the sealant to the exposed male part of the fitting collar so that the sealer is on the inside of the joint and fully protected by the metal of the duct fitting. Apply one brush coat of the sealant over the outside of the joint to at least 2 inch band width covering all screw heads and joint gap. Dents in the male portion of the slip fitting collar are not acceptable.
- g. Fabricate outdoor air intake ducts and plenums with watertight soldered or brazed joints and seams.

2.9.1.1 Metallic Flexible Duct

- a. Provide duct that conforms to UL 181 and NFPA 90A with factory-applied insulation, vapor barrier, and end connections. Provide duct assembly that does not exceed 25 for flame spread and 50 for smoke developed. Provide ducts designed for working pressures of 2 inches water gauge positive and 1.5 inches water gauge negative. Provide flexible round duct length that does not exceed 5 feet. Secure connections by applying adhesive for 2 inches over rigid duct, apply flexible duct 2 inches over rigid duct, apply metal clamp, and provide minimum of three No. 8 sheet metal screws through clamp and rigid duct.
- b. Inner duct core: Provide interlocking spiral or helically corrugated flexible core constructed of zinc-coated steel, aluminum, or stainless steel; or constructed of inner liner of continuous galvanized spring steel wire helix fused to continuous, fire-retardant, flexible vapor barrier film, inner duct core.
- c. Insulation: Provide inner duct core that is insulated with mineral fiber blanket type flexible insulation, minimum of 1 inch thick. Provide insulation covered on exterior with manufacturer's standard fire retardant vapor barrier jacket for flexible round duct.

2.9.1.2 Insulated Nonmetallic Flexible Duct Runouts

Use flexible duct runouts only where indicated. Runout length is indicated on the drawings, and is not to exceed 5 feet. Provide runouts that are preinsulated, factory fabricated, and that comply with NFPA 90A and UL 181. Provide either field or factory applied vapor barrier. Provide not less than 20 ounce glass fabric duct connectors coated on both sides with neoprene. Where coil induction or high velocity units are supplied with vertical air inlets, use a streamlined, vaned and mitered elbow transition piece for connection to the flexible duct or hose. Provide a die-stamped elbow and not a flexible connector as the last elbow to these units other than the vertical air inlet type. Insulated flexible connectors are allowed as runouts. Provide insulated material and vapor barrier that conform to the requirements of Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. Do not expose the insulation material surface to the air stream.

2.9.1.3 General Service Duct Connectors

Provide a flexible duct connector approximately 6 inches in width where sheet metal connections are made to fans or where ducts of dissimilar metals are connected. For round/oval ducts, secure the flexible material by stainless steel or zinc-coated, iron clinch-type draw bands. For rectangular ducts, install the flexible material locked to metal collars using normal duct construction methods. Provide a composite connector system that complies with NFPA 701 and is classified as "flame-retardant fabrics" in UL Bld Mat Dir.

2.9.1.4 High Temperature Service Duct Connections

Provide material that is approximately 3/32 inch thick, 35 to 40-ounce per square yard weight, plain weave fibrous glass cloth with, nickel/chrome wire reinforcement for service in excess of 1200 degrees F.

2.9.1.5 Aluminum Ducts

ASTM B209, alloy 3003-H14 for aluminum sheet and alloy 6061-T6 or equivalent strength for aluminum connectors and bar stock.

2.9.1.6 Copper Sheets

ASTM B152/B152M, light cold rolled temper.

2.9.1.7 Corrosion Resisting (Stainless) Steel Sheets

ASTM A167

2.9.2 Duct Access Doors

Provide hinged access doors conforming to SMACNA 1966 in ductwork and plenums where indicated and at all air flow measuring primaries, automatic dampers, fire dampers, coils, thermostats, and other apparatus requiring service and inspection in the duct system. Provide access doors upstream and downstream of air flow measuring primaries and heating and cooling coils. Provide doors that are a minimum 15 by 18 inches, unless otherwise shown. Where duct size does not accommodate this size door, make the doors as large as practicable. Equip doors 24 by 24 inches or larger with fasteners operable from inside and outside the duct. Use insulated type doors in insulated ducts.

2.9.3 Fire Dampers

Use 1.5 hour rated fire dampers unless otherwise indicated. Provide fire dampers that conform to the requirements of NFPA 90A and UL 555. Perform the fire damper test as outlined in NFPA 90A. Provide a pressure relief door upstream of the fire damper. If the ductwork connected to the fire damper is to be insulated then provide a factory installed pressure relief damper. Provide automatic operating fire dampers with a dynamic rating suitable for the maximum air velocity and pressure differential to which it is subjected. Provide fire dampers approved for the specific application, and install according to their listing. Equip fire dampers with a steel sleeve or adequately sized frame installed in such a manner that disruption of the attached ductwork, if any, does not impair the operation of the damper. Equip sleeves or frames with perimeter mounting angles attached on both sides of the wall or floor opening. Construct ductwork in fire-rated floor-ceiling or roof-ceiling assembly systems with

air ducts that pierce the ceiling of the assemblies in conformance with UL Fire Resistance. Provide in the air stream fire dampers. Install dampers that do not reduce the duct or the air transfer opening cross-sectional area. Install dampers so that the centerline of the damper depth or thickness is located in the centerline of the wall, partition or floor slab depth or thickness. Unless otherwise indicated, comply with the installation details given in SMACNA 1819 and in manufacturer's instructions for fire dampers. Perform acceptance testing of fire dampers according to paragraph Fire Damper Acceptance Test and NFPA 90A.

2.9.4 Manual Balancing Dampers

Furnish manual balancing dampers with accessible operating mechanisms. Use chromium plated operators (with all exposed edges rounded) in finished portions of the building. Provide manual volume control dampers that are operated by locking-type quadrant operators. Install dampers that are 2 gauges heavier than the duct in which installed. Unless otherwise indicated, provide opposed blade type multileaf dampers with maximum blade width of 12 inches. Provide access doors or panels for all concealed damper operators and locking setscrews. Provide stand-off mounting brackets, bases, or adapters not less than the thickness of the insulation when the locking-type quadrant operators for dampers are installed on ducts to be thermally insulated, to provide clearance between the duct surface and the operator. Provide stand-off mounting items that are integral with the operator or standard accessory of the damper manufacturer.

2.9.5 Air Supply And Exhaust Air Dampers

Provide outdoor air supply and exhaust air dampers that have a maximum leakage rate when tested in accordance with AMCA 500-D as required by ASHRAE 90.1 - IP, including maximum Damper Leakage for:

- a. Climate Zones 1,2,6,7,8 the maximum damper leakage at 1.0 inch w.g. for motorized dampers is 4 cfm per square foot of damper area and non-motorized dampers are not allowed.
- b. All other Climate Zones the maximum damper leakage at 1.0 inch w.g. is 10 cfm per square foot and for non-motorized dampers is 20 cfm per square foot of damper area.

Dampers smaller than 24 inches in either direction may have leakage of 40 cfm per square foot.

2.9.6 Air Deflectors (Volume Extractors) and Branch Connections

Provide air deflectors (volume extractors) at all duct mounted supply outlets, at takeoff or extension collars to supply outlets, at duct branch takeoff connections, and at 90 degree elbows, as well as at locations as indicated on the drawings or otherwise specified. Conical branch connections or 45 degree entry connections are allowed in lieu of deflectors for branch connections. Furnish all air deflectors (volume extractors), except those installed in 90 degree elbows, with an approved means of adjustment. Provide easily accessible means for adjustment inside the duct or from an adjustment with sturdy lock on the face of the duct. When installed on ducts to be thermally insulated, provide external adjustments with stand-off mounting brackets, integral with the adjustment device, to provide clearance between the duct surface and the adjustment

device not less than the thickness of the thermal insulation. Provide factory-fabricated air deflectors consisting of curved turning vanes or louver blades designed to provide uniform air distribution and change of direction with minimum turbulence or pressure loss. Provide factory or field assembled air deflectors (volume extractors). Make adjustment from the face of the diffuser or by position adjustment and lock external to the duct. Provide stand-off brackets on insulated ducts as described herein. Provide fixed air deflectors (volume extractors), also called turning vanes, in 90 degree elbows.

2.9.7 Plenums and Casings for Field-Fabricated Units

2.9.7.1 Plenum and Casings

Fabricate and erect plenums and casings as shown in SMACNA 1966, as applicable. Construct system casing of not less than 16 gauge galvanized sheet steel. Furnish cooling coil drain pans with 1 inch threaded outlet to collect condensation from the cooling coils. Fabricate drain pans from not lighter than 16 gauge steel, galvanized after fabrication or of 18 gauge corrosion-resisting sheet steel conforming to ASTM A167, Type 304, welded and stiffened. Thermally insulate drain pans exposed to the atmosphere to prevent condensation. Coat insulation with a flame resistant waterproofing material. Provide separate drain pans for each vertical coil section, and a separate drain line for each pan. Size pans to ensure capture of entrained moisture on the downstream-air side of the coil. Seal openings in the casing, such as for piping connections, to prevent air leakage. Size the water seal for the drain to maintain a pressure of at least 2 inch water gauge greater than the maximum negative pressure in the coil space.

2.9.7.2 Casing

Terminate casings at the curb line and bolt each to the curb using galvanized angle, as indicated in SMACNA 1966.

2.9.7.3 Access Doors

Provide access doors in each section of the casing. Weld doorframes in place, gasket each door with neoprene, hinge with minimum of two brass hinges, and fasten with a minimum of two brass tension fasteners operable from inside and outside of the casing. Where possible, make doors 36 by 18 inches and locate them 18 inches above the floor. Where the space available does not accommodate doors of this size, use doors as large as the space accommodates. Swing doors so that fan suction or pressure holds doors in closed position, airtight. Provide a push-button station, located inside the casing, to stop the supply.

2.9.7.4 Factory-Fabricated Insulated Sheet Metal Panels

Factory-fabricated components are allowed for field-assembled units, provided all requirements specified for field-fabricated plenums and casings are met. Provide panels of modular design, pretested for structural strength, thermal control, condensation control, and acoustical control. Seal and insulate panel joints. Provide and gasket access doors to prevent air leakage. Provide panel construction that is not less than 20 gauge galvanized sheet steel, assembled with fasteners treated against corrosion. Provide standard length panels that deflect not more than 1/2 inch under operation. Construct details, including joint sealing, not specifically covered, as indicated in SMACNA 1966. Construct the plenums

and casings to withstand the specified internal pressure of the air systems.

2.9.7.5 Duct Liner

Unless otherwise specified, duct liner is not permitted.

2.9.8 Sound Attenuation Equipment

2.9.8.1 Systems with total pressure above 4 Inches Water Gauge

Provide sound attenuators on the discharge duct of each fan operating at a total pressure above 4 inch water gauge, and, when indicated, at the intake of each fan system. Provide sound attenuators elsewhere as indicated. Provide factory fabricated sound attenuators, tested by an independent laboratory for sound and performance characteristics. Provide a net sound reduction as indicated. Maximum permissible pressure drop is not to exceed 0.63 inch water gauge. Construct traps to be airtight when operating under an internal static pressure of 10 inch water gauge. Provide air-side surface capable of withstanding air velocity of 10,000 fpm. Certify that the equipment can obtain the sound reduction values specified after the equipment is installed in the system and coordinated with the sound information of the system fan to be provided. Provide sound absorbing material conforming to ASTM C1071, Type I or II. Provide sound absorbing material that meets the fire hazard rating requirements for insulation specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. For connection to ductwork, provide a duct transition section. Factory fabricated double-walled internally insulated spiral lock seam and round duct and fittings designed for high pressure air system can be provided if complying with requirements specified for factory fabricated sound attenuators, in lieu of factory fabricated sound attenuators. Construct the double-walled duct and fittings from an outer metal pressure shell of zinc-coated steel sheet, 1 inch thick acoustical blanket insulation, and an internal perforated zinc-coated metal liner. Provide a sufficient length of run to obtain the noise reduction coefficient specified. Certify that the sound reduction value specified can be obtained within the length of duct run provided. Provide welded or spiral lock seams on the outer sheet metal of the double-walled duct to prevent water vapor penetration. Provide duct and fittings with an outer sheet that conforms to the metal thickness of high-pressure spiral and round ducts and fittings shown in SMACNA 1966. Provide acoustical insulation with a thermal conductivity "k" of not more than 0.27 Btu/inch/square foot/hour/degree F at 75 degrees F mean temperature. Provide an internal perforated zinc-coated metal liner that is not less than 24 gauge with perforations not larger than 1/4 inch in diameter providing a net open area not less than 10 percent of the surface.

2.9.8.2 System with total pressure of 4 Inch Water Gauge and Lower

Use sound attenuators only where indicated. Provide factory fabricated sound attenuators that are constructed of galvanized steel sheets. Provide attenuator with outer casing that is not less than 22 gauge. Provide fibrous glass acoustical fill. Provide net sound reduction indicated. Obtain values on a test unit not less than 24 by 24 inches outside dimensions made by a certified nationally recognized independent acoustical laboratory. Provide air flow capacity as indicated or required. Provide pressure drop through the attenuator that does not exceed the value indicated, or that is not in excess of 15 percent of the total external static pressure of the air handling system, whichever is

less. Acoustically test attenuators with metal duct inlet and outlet sections while under the rated air flow conditions. Include with the noise reduction data the effects of flanking paths and vibration transmission. Construct sound attenuators to be airtight when operating at the internal static pressure indicated or specified for the duct system, but in no case less than 2 inch water gauge.

2.9.8.3 Acoustical Duct Liner

Use fibrous glass designed or flexible elastomeric duct liner for lining ductwork and conforming to the requirements of ASTM C1071, Type I and II. Provide uniform density, graduated density, or dual density liner composition, as standard with the manufacturer. Provide not less than 1 inch thick coated lining. Where acoustical duct liner is used, provide the thermal equivalent of the insulation specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS for liner or combination of liner and insulation applied to the exterior of the ductwork. Increase duct sizes shown to compensate for the thickness of the lining used. In lieu of sheet metal duct with field-applied acoustical lining, provide acoustically equivalent lengths of fibrous glass duct, elastomeric duct liner or factory fabricated double-walled internally insulated duct with perforated liner.

2.9.9 Diffusers, Registers, and Grilles

Provide factory-fabricated units of corrosion-resistant steel that distribute the specified quantity of air evenly over space intended without causing noticeable drafts, air movement faster than 50 fpm in occupied zone, or dead spots anywhere in the conditioned area. Provide outlets for diffusion, spread, throw, and noise level as required for specified performance. Certify performance according to ASHRAE 70. Provide sound rated and certified inlets and outlets according to ASHRAE 70. Provide sound power level as indicated. Provide diffusers and registers with volume damper with accessible operator, unless otherwise indicated; or if standard with the manufacturer, an automatically controlled device is acceptable. Provide opposed blade type volume dampers for all diffusers and registers, except linear slot diffusers. Provide linear slot diffusers with round or elliptical balancing dampers. Where the inlet and outlet openings are located less than 7 feet above the floor, protect them by a grille or screen according to NFPA 90A.

2.9.9.1 Diffusers

Provide diffuser types indicated. Furnish ceiling mounted units with anti-smudge devices, unless the diffuser unit minimizes ceiling smudging through design features. Provide diffusers with air deflectors of the type indicated. Provide air handling troffers or combination light and ceiling diffusers conforming to the requirements of UL Electrical Construction for the interchangeable use as cooled or heated air supply diffusers or return air units. Install ceiling mounted units with rims tight against ceiling. Provide sponge rubber gaskets between ceiling and surface mounted diffusers for air leakage control. Provide suitable trim for flush mounted diffusers. For connecting the duct to diffuser, provide duct collar that is airtight and does not interfere with volume controller. Provide return or exhaust units that are similar to supply diffusers.

2.9.9.2 Registers and Grilles

Provide units that are four-way directional-control type, except provide return and exhaust registers that are fixed horizontal or vertical louver type similar in appearance to the supply register face. Furnish registers with sponge-rubber gasket between flanges and wall or ceiling. Install wall supply registers at least 6 inches below the ceiling unless otherwise indicated. Locate return and exhaust registers 6 inches above the floor unless otherwise indicated. Achieve four-way directional control by a grille face which can be rotated in 4 positions or by adjustment of horizontal and vertical vanes. Provide grilles as specified for registers, without volume control damper.

2.9.10 Louvers

Provide louvers for installation in exterior walls that are associated with the air supply and distribution system as specified in Section 07 60 00 FLASHING AND SHEET METAL .

2.9.11 Air Vents, Penthouses, and Goosenecks

Fabricate air vents, penthouses, and goosenecks from galvanized steel or aluminum sheets with galvanized or aluminum structural shapes. Provide sheet metal thickness, reinforcement, and fabrication that conform to SMACNA 1966. Accurately fit and secure louver blades to frames. Fold or bead edges of louver blades for rigidity and baffle these edges to exclude driving rain. Provide air vents, penthouses, and goosenecks with bird screen.

2.9.12 Bird Screens and Frames

Provide bird screens that conform to ASTM E2016, No. 2 mesh, aluminum or stainless steel. Provide "medium-light" rated aluminum screens. Provide "light" rated stainless steel screens. Provide removable type frames fabricated from either stainless steel or extruded aluminum.

2.9.13 Radon Exhaust Ductwork

Fabricate radon exhaust ductwork installed in or beneath slabs from Schedule 40 PVC pipe that conforms to ASTM D1785. Provide fittings that conform to ASTM D2466. Use solvent cement conforming to ASTM D2564 to make joints. Otherwise provide metal radon exhaust ductwork as specified herein.

2.10 AIR SYSTEMS EQUIPMENT

2.10.1 Fans

Test and rate fans according to AMCA 210. Calculate system effect on air moving devices in accordance with AMCA 201 where installed ductwork differs from that indicated on drawings. Install air moving devices to minimize fan system effect. Where system effect is unavoidable, determine the most effective way to accommodate the inefficiencies caused by system effect on the installed air moving device. The sound power level of the fans must not exceed 85 dBA when tested according to AMCA 300 and rated in accordance with AMCA 301. Provide all fans with an AMCA seal. Connect fans to the motors either directly or indirectly with V-belt drive. Use V-belt drives designed for not less than 150 percent of the connected driving capacity. Provide variable pitch motor sheaves for 15 hp and

below, and fixed pitch as defined by AHRI Guideline D (A fixed-pitch sheave is provided on both the fan shaft and the motor shaft. This is a non-adjustable speed drive.). Select variable pitch sheaves to drive the fan at a speed which can produce the specified capacity when set at the approximate midpoint of the sheave adjustment. When fixed pitch sheaves are furnished, provide a replaceable sheave when needed to achieve system air balance. Provide motors for V-belt drives with adjustable rails or bases. Provide removable metal guards for all exposed V-belt drives, and provide speed-test openings at the center of all rotating shafts. Provide fans with personnel screens or guards on both suction and supply ends, except that the screens need not be provided, unless otherwise indicated, where ducts are connected to the fan. Provide fan and motor assemblies with vibration-isolation supports or mountings as indicated. Use vibration-isolation units that are standard products with published loading ratings. Select each fan to produce the capacity required at the fan static pressure indicated. Provide sound power level as indicated. Obtain the sound power level values according to AMCA 300. Provide standard AMCA arrangement, rotation, and discharge as indicated. Provide power ventilators that conform to UL 705 and have a UL label.

2.10.1.1 Centrifugal Fans

Provide fully enclosed, single-width single-inlet, or double-width double-inlet centrifugal fans, with AMCA Pressure Class I, II, or III as required or indicated for the design system pressure. Provide impeller wheels that are rigidly constructed and accurately balanced both statically and dynamically. Provide forward curved or backward-inclined airfoil design fan blades in wheel sizes up to 30 inches. Provide backward-inclined airfoil design fan blades for wheels over 30 inches in diameter. Provide fan wheels over 36 inches in diameter with overhung pulleys and a bearing on each side of the wheel. Provide fan wheels 36 inches or less in diameter that have one or more extra long bearings between the fan wheel and the drive. Provide sleeve type, self-aligning and self-oiling bearings with oil reservoirs, or precision self-aligning roller or ball-type with accessible grease fittings or permanently lubricated type. Connect grease fittings to tubing for serviceability from a single accessible point. Provide L50 rated bearing life at not less than 200,000 hours as defined by ABMA 9 and ABMA 11. Provide steel, accurately finished fan shafts, with key seats and keys for impeller hubs and fan pulleys. Provide fan outlets of ample proportions, designed for the attachment of angles and bolts for attaching flexible connections. Provide manually operated inlet vanes on suction inlets. Provide manually operated outlet dampers. Unless otherwise indicated, provide motors that do not exceed 1800 rpm and have dripproof enclosures. Provide magnetic reduced-voltage-start type motor starters with weather-resistant enclosure.

2.10.1.2 In-Line Centrifugal Fans

Provide in-line fans with centrifugal backward inclined blades, stationary discharge conversion vanes, internal and external belt guards, and adjustable motor mounts. Mount fans in a welded tubular casing. Provide a fan that axially flows the air in and out. Streamline inlets with conversion vanes to eliminate turbulence and provide smooth discharge air flow. Enclose and isolate fan bearings and drive shafts from the air stream. Provide precision, self-aligning ball or roller type fan bearings that are sealed against dust and dirt and are permanently lubricated. Provide L50 rated bearing life at not less than 200,000 hours as defined by ABMA 9 and ABMA 11. Provide motors with dripproof enclosure.

2.10.1.3 Axial Flow Fans

Provide axial flow fans complete with drive components and belt guard, with steel housing, cast fan wheel, cast or welded steel diffusers, fan shaft, bearings, and mounting frame as a factory-assembled unit. Provide fan wheels that are dynamically balanced and keyed to the fan shaft, with radially projecting blades of airfoil cross-section. Enclose and isolate fan bearings and drive shafts from the air stream. Permanently lubricate fan bearings or provide them with accessible grease fittings. Provide precision self-aligning ball or roller type fan bearings that are sealed against dust and dirt. Provide fan bearings that have a L50 rated bearing life at not less than 200,000 hours of operation as defined by ABMA 9 and ABMA 11. Provide fan inlets with an aerodynamically shaped bell and an inlet cone. Install diffuser or straightening vanes at the fan discharge to minimize turbulence and provide smooth discharge air flow. Furnish fan unit with inlet screen, and manual operation adjustable inlet vanes. Unless otherwise indicated, provide motors that do not exceed 1800 rpm and have dripproof enclosure. Provide magnetic motor starters across-the-line with weather-resistant enclosure.

2.10.1.4 Panel Type Power Wall Ventilators

Provide propeller type fans, assembled on a reinforced metal panel with venturi opening spun into panel. Provide direct or V-belt driven fans with wheels less than 24 inches in diameter and provide V-belt driven fans with wheels 24 inches in diameter and larger. Provide fans with wall mounting collar. Provide lubricated bearings. Equip fans with wheel and motor side metal or wire guards which have a corrosion-resistant finish. Provide dripproof type motor enclosure. Install motor operated backdraft dampers where indicated.

2.10.1.5 Centrifugal Type Power Wall Ventilators

Provide direct driven centrifugal type fans with backward inclined, non-overloading wheel. Provide removable and weatherproof motor housing. Provide unit housing that is designed for sealing to building surface and for discharge and condensate drippage away from building surface. Construct housing of heavy gauge aluminum. Equip unit with an aluminum or plated steel wire discharge bird screen, disconnect switch, manufacturer's standard motor-operated damper, an airtight and liquid-tight metallic wall sleeve. Provide dripproof type motor enclosure. Use only lubricated bearings.

2.10.1.6 Centrifugal Type Power Roof Ventilators

Provide direct driven centrifugal type fans with backward inclined, non-overloading wheel. Provide hinged or removable and weatherproof motor compartment housing, constructed of heavy gauge aluminum. Provide fans with birdscreen, disconnect switch, motorized dampers, and . Provide dripproof type motor enclosure. Provide centrifugal type kitchen exhaust fans according to UL 705 and NFPA 96, fitted with V-belt drive, round hood, and windband upblast discharge configuration, integral residue trough and collection device, with motor and power transmission components located in outside positively air ventilated compartment. Use only lubricated bearings. If there is a conflict between NFPA 96 and UL 705 the most stringent wording must be adhered to.

2.10.1.7 Propeller Type Power Roof Ventilators

Provide direct driven fans. Provide hinged or removable weathertight fan housing, fitted with framed rectangular base constructed of aluminum or galvanized steel. Provide totally enclosed fan cooled type motors. Furnish motors with nonfusible, horsepower rated, manual disconnect mount on unit. Furnish fans with motor operated dampers, birdscreen. Use only lubricated bearings.

2.10.1.8 Air-Curtain Fans

Provide fans that conform to AMCA 220 with AMCA seal. Furnish air curtains with a weatherproof housing constructed of high impact plastic or minimum 18 gauge rigid welded steel. Provide backward curved, non-overloading, centrifugal type fan wheels, accurately balanced statically and dynamically. Provide motors with totally enclosed fan cooled enclosures. Provide remote manual type motor starters with weather-resistant enclosure actuated when the doorway served is open. Provide air curtains that attain the air velocities specified within 2 seconds following activation. Provide bird screens at air intake and discharge openings. Provide air curtain unit or a multiple unit installation that is at least as wide as the opening to be protected. Provide the air discharge openings to permit outward adjustment of the discharge air. Place installation and adjust according to the manufacturer's written recommendation. Furnish directional controls on air curtains for service windows for easy clean or convenient removal. Design air curtains to prevent the adjustment of the air velocities specified. Make the interior surfaces of the air curtain units accessible for cleaning. Provide certified test data indicating that the fan can provide the air velocities required when fan is mounted as indicated. Provide air curtains designed as fly fans unless otherwise indicated.

2.10.1.9 Ceiling Exhaust Fans

Provide centrifugal type, direct driven suspended cabinet-type ceiling exhaust fans. Provide fans with acoustically insulated housing. Provide chatter-proof backdraft damper. Provide egg-crate design or louver design integral face grille. Mount fan motors on vibration isolators. Furnish unit with mounting flange for hanging unit from above. Provide U.L. listed fans. Provide PL-109-58 labeled ceiling exhaust fan product. Provide proof of PL-109-58 label for ceiling exhaust fan product.

2.10.2 Coils

Provide fin-and-tube type coils constructed of seamless copper tubes and aluminum fins mechanically bonded or soldered to the tubes. Provide copper tube wall thickness that is a minimum of 0.020 inches.. Provide casing and tube support sheets that are not lighter than 16 gauge galvanized steel, formed to provide structural strength. When required, provide multiple tube supports to prevent tube sag. Mount coils for counterflow service. Rate and certify coils to meet the requirements of AHRI 410.

2.10.2.1 Direct-Expansion Coils

Provide suitable direct-expansion coils for the refrigerant involved. Provide refrigerant piping that conforms to ASTM B280 and clean, dehydrate and seal. Provide seamless copper tubing suction headers or seamless or resistance welded steel tube suction headers with copper connections.

Provide supply headers that consist of a distributor which distributes the refrigerant through seamless copper tubing equally to all circuits in the coil. Provide circuited tubes to ensure minimum pressure drop and maximum heat transfer. Provide circuiting that permits refrigerant flow from inlet to suction outlet without causing oil slugging or restricting refrigerant flow in coil. Provide field installed coils which are completely dehydrated and sealed at the factory upon completion of pressure tests. Pressure test coils in accordance with UL 1995.

2.10.2.2 Water Coils

Install water coils with a pitch of not less than 1/8 inch/foot of the tube length toward the drain end. Use headers constructed of cast iron, welded steel or copper. Furnish each coil with a plugged vent and drain connection extending through the unit casing. Provide removable water coils with drain pans. Pressure test coils in accordance with UL 1995.

2.10.2.3 Steam Heating Coils

Construct steam coils from cast semisteel, welded steel or copper headers, and copper tubes. Construct headers from cast iron, welded steel or copper. Provide fin tube and header section that float within the casing to allow free expansion of tubing for coils subject to high pressure steam service. Provide each coil with a field or factory installed vacuum breaker. Provide single-tube type coils with tubes not less than 1/2 inch outside diameter, except for steam preheat coils. Provide supply headers that distribute steam evenly to all tubes at the indicated steam pressure. Factory test coils to ensure that, when supplied with a uniform face velocity, temperature across the leaving side is uniform with a maximum variation of no more than 5 percent. Pressure test coils in accordance with UL 1995.

2.10.2.4 Steam Preheat (Nonfreeze) Coils

Provide steam-distribution-tube type steam (nonfreeze) coils with condensing tubes not less than 1 inch outside diameter for tube lengths 60 inches and over and 1/2 inch outside diameter for tube lengths under 60 inches. Construct headers from cast iron, welded steel, or copper. Provide distribution tubes that are not less than 5/8 inch outside diameter for tube lengths 60 inches and over and 3/8 inch outside diameter for tube lengths under 60 inches with orifices to discharge steam to condensing tubes. Install distribution tubes concentric inside of condensing tubes and hold securely in alignment. Limit maximum length of a single coil to 144 inches. Factory test coils to ensure that, when supplied with a uniform face velocity, temperature across the leaving side is uniform with a maximum variation of no more than 5 percent. Pressure test coils in accordance with UL 1995.

2.10.3 Air Filters

List air filters according to requirements of UL 900, except list high efficiency particulate air filters of 99.97 percent efficiency by the DOP Test method under the Label Service to meet the requirements of UL 586.

2.10.3.1 Extended Surface Pleated Panel Filters

Provide 2 inch depth, sectional, disposable type filters of the size indicated with a MERV of 8 when tested according to ASHRAE 52.2. Provide initial resistance at 500 fpm that does not exceed 0.36 inches water gauge.

Provide UL Class 2 filters, and nonwoven cotton and synthetic fiber mat media. Attach a wire support grid bonded to the media to a moisture resistant fiberboard frame. Bond all four edges of the filter media to the inside of the frame to prevent air bypass and increase rigidity.

2.10.3.2 Extended Surface Nonsupported Pocket Filters

Provide 30 inch depth, sectional, replaceable dry media type filters of the size indicated with a MERV of 13 when tested according to ASHRAE 52.2. Provide initial resistance at 500 fpm that does not exceed 0.45 inches water gauge. Provide UL Class 1 filters. Provide fibrous glass media, supported in the air stream by a wire or non-woven synthetic backing and secured to a galvanized steel metal header. Provide pockets that do not sag or flap at anticipated air flows. Install each filter in a factory preassembled, side access housing or a factory-made sectional frame bank, as indicated.

2.10.3.3 Cartridge Type Filters

Provide 12 inch depth, sectional, replaceable dry media type filters of the size indicated with a MERV of 13 when tested according to ASHRAE 52.2. Provide initial resistance at 500 fpm that does not exceed 0.56 inches, water gauge. Provide UL class 1 filters, and pleated microglass paper media with corrugated aluminum separators, sealed inside the filter cell to form a totally rigid filter assembly. Fluctuations in filter face velocity or turbulent airflow have no effect on filter integrity or performance. Install each filter in a factory preassembled side access housing, or a factory-made sectional frame bank, as indicated.

2.10.3.4 Sectional Cleanable Filters

Provide 2 inch thick cleanable filters. Provide viscous adhesive in 5 gallon containers in sufficient quantity for 12 cleaning operations and not less than one quart for each filter section. Provide one washing and charging tank for every 100 filter sections or fraction thereof; with each washing and charging unit consisting of a tank and single drain rack mounted on legs and drain rack with dividers and partitions to properly support the filters in the draining position.

2.10.3.5 Replaceable Media Filters

Provide the dry-media type replaceable media filters, of the size required to suit the application. Provide filtering media that is not less than 2 inches thick fibrous glass media pad supported by a structural wire grid or woven wire mesh. Enclose pad in a holding frame of not less than 16 gauge galvanized steel, equipped with quick-opening mechanism for changing filter media. Base the air flow capacity of the filter on net filter face velocity not exceeding 300 fpm, with initial resistance of 0.13 inches water gauge. Provide MERV that is not less than 8 when tested according to ASHRAE 52.2.

2.10.3.6 Automatic Renewable Media Filters

Provide the following:

- a. Automatic, renewable media filters consisting of a horizontal or vertical traveling curtain of adhesive-coated bonded fibrous glass supplied in convenient roll form, and filter that does not require water supply, sewer connections, adhesive reservoir, or sprinkler

equipment as part of the operation and maintenance requirements.

- b. Basic frame that is fabricated of not less than 14 gauge galvanized steel, and sectional design filters with each section of each filter fully factory assembled, requiring no field assembly other than setting in place next to any adjacent sections and the installation of media in roll form.
- c. Each filter complete with initial loading of filter media drive motor adequate to handle the number of sections involved, and painted steel control box containing a warning light to indicate media runout, a runout switch, and a Hand-Off-Auto selector switch.
- d. Media feed across the filter face in increments automatically controlled as determined by filter pressure differential to provide substantially constant operating resistance to airflow and varying not more than plus or minus 10 percent. Roll or enclose media in such a way that collected particulates can not re-entrain.
- e. Rolls of clean media, no less than 65 feet long, rerolled on disposable spools in the rewind section of the filter after the media has accumulated its design dirt load. Equip rewind section with a compression panel to tightly rewind used media for ease of handling. Provide media made of continuous, bonded fibrous glass material, UL Class 2, that does not compress more than 1/4 inch when subjected to air flow at 500 fpm. Factory charge media with an odorless and flame retardant adhesive which does not flow while in storage nor when subjected to temperatures up to 175 degrees F. Support media on both the leaving and entering air faces. Clean media must have initial resistance that does not exceed 0.18 inch water gauge at its rated velocity of 500 fpm. Set control so that the resistance to air flow is between 0.40-and 0.50 inch water gauge unless otherwise indicated.
- f. Dust holding capacity, of 80 percent average arrestance under these operating conditions, when operating at a steady state with an upper operating resistance of 0.50 inch water gauge, that is at least 592 (55) grams of ASHRAE Standard Test Dust per square foot of media area, when tested according to the dynamic testing provisions of ASHRAE 52.2.
- g. The horizontal type automatic renewable media filters, when used in conjunction with factory fabricated air handling units, that are dimensionally compatible with the connecting air handling units, and horizontal type filter housings with all exposed surfaces factory insulated internally with 1 inch, 1-1/2 pound density neoprene coated fibrous glass with thermal conductivity not greater than 0.27 Btu/hour/degree F/square foot/inch of thickness.
- h. Access doors for horizontal filters with double wall construction as specified for plenums and casings for field-fabricated units in paragraph DUCT SYSTEMS.

2.10.3.7 Electrostatic Filters

Provide the following:

- a. The combination dry agglomerator/extended surface, nonsupported pocket electrostatic filters or the combination dry agglomerator/automatic renewable, media (roll) type electrostatic filters, as indicated (except as modified). Supply each dry agglomerator electrostatic air

filter with the correct quantity of fully housed power packs and equip with silicon rectifiers, manual reset circuit breakers, low voltage safety cutout, relays for field wiring to remote indication of primary and secondary voltages, with lamps mounted in the cover to indicate these functions locally. Equip power pack enclosure with external mounting brackets, and low and high voltage terminals fully exposed with access cover removed for ease of installation. Furnish interlock safety switches for each access door and access panel that permits access to either side of the filter, so that the filter is de-energized in the event that a door or panel is opened.

- b. Ozone generation within the filter that does not exceed five parts per one hundred million parts of air. Locate high voltage insulators in a serviceable location outside the moving air stream or on the clean air side of the unit. Fully expose ionizer wire supports and furnish ionizer wires precut to size and with formed loops at each end to facilitate ionizer wire replacement.
- c. Agglomerator cell plates that allow proper air stream entrainment of agglomerates and prevent excessive residual dust build-up, with cells that are open at the top and bottom to prevent accumulation of agglomerates which settle by gravity. Where the dry agglomerator electrostatic filter is indicated to be the automatic renewable media type, provide a storage section that utilizes a horizontal or vertical traveling curtain of adhesive-coated bonded fibrous glass for dry agglomerator storage section service supplied in 65 foot lengths in convenient roll form. Otherwise, provide section construction and roll media characteristics as specified for automatic renewable media filters. Also a dry agglomerator/renewable media combination with an initial air flow resistance, after installation of clean media, that does not exceed 0.25 inch water gauge at 500 fpm face velocity.
- d. A MERV of the combination that is not less than 15 when tested according to ASHRAE 52.2 at an average operating resistance of 0.50 inch water gauge. Where the dry agglomerator electrostatic filter is indicated to be of the extended surface nonsupported pocket filter type, provide a storage section as specified for extended surface non-supported pocket filters, with sectional holding frames or side access housings as indicated.
- e. A dry agglomerator/extended surface nonsupported pocket filter section combination with initial air flow resistance, after installation of clean filters, that does not exceed 0.65 inch water gauge at 500 fpm face velocity, with a MERV of the combination not less than 16 when tested according to ASHRAE 52.2. Furnish front access filters with full height air distribution baffles and upper and lower mounting tracks to permit the baffles to be moved for agglomerator cell inspection and service. When used in conjunction with factory fabricated air handling units, supply side access housings which have dimensional compatibility.

2.10.3.8 High-Efficiency Particulate Air (HEPA) Filters

Provide HEPA filters that meet the requirements of IEST RP-CC-001 and are individually tested and certified to have an efficiency of not less than 95 percent, and an initial resistance at fpm that does not exceed inches water gauge. Provide filters that are constructed by pleating a continuous sheet of filter medium into closely spaced pleats separated by corrugated aluminum or mineral-fiber inserts, strips of filter medium, or

by honeycomb construction of the pleated filter medium. Provide interlocking, dovetailed, molded neoprene rubber gaskets of 5-10 durometer that are cemented to the perimeter of the upstream face of the filter cell sides. Provide self-extinguishing rubber-base type adhesive or other materials conforming to fire hazard classification specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. Provide filter cell sides that are galvanized steel assembled in a rigid manner. Provide overall cell side dimensions that are correct to 1/16 inch, and squareness that is maintained to within 1/8 inch. Provide holding frames that use spring loaded fasteners or other devices to seal the filter tightly within it and that prevent any bypass leakage around the filter during its installed life. Provide air capacity and the nominal depth of the filter as indicated. Install each filter in a factory preassembled side access housing or a factory-made sectional supporting frame as indicated. Provide prefilters of the type, construction and efficiency indicated.

2.10.3.9 Holding Frames

Fabricate frames from not lighter than 16 gauge sheet steel with rust-inhibitor coating. Equip each holding frame with suitable filter holding devices. Provide gasketed holding frame seats. Make all joints airtight.

2.10.3.10 Filter Gauges

Provide dial type filter gauges, diaphragm actuated draft for all filter stations, including those filters which are furnished as integral parts of factory fabricated air handling units. Provide gauges that are at least 3-7/8 inches in diameter, with white dials with black figures, and graduations with a minimum range of 1 inch of water beyond the specified final resistance for the filter bank on which each gauge is applied. Provide each gauge with a screw operated zero adjustment and two static pressure tips with integral compression fittings, two molded plastic vent valves, two 5 foot minimum lengths of 1/4 inch diameter aluminum tubing, and all hardware and accessories for gauge mounting.

2.11 AIR HANDLING UNITS

2.11.1 Factory-Fabricated Air Handling Units

Provide single-zone draw-through type units as indicated. Units must include fans, coils, airtight insulated casing, secondary filter sections, adjustable V-belt drives, belt guards for externally mounted motors, access sections where indicated, combination sectional filter-mixing box, vibration-isolators, and appurtenances required for specified operation. Provide vibration isolators as indicated. Physical dimensions of each air handling unit must be suitable to fit space allotted to the unit with the capacity indicated. Provide air handling unit that is rated in accordance with AHRI 430 and AHRI certified for cooling.

2.11.1.1 Casings

Provide the following:

- a. Inner casing of double-wall units that are a minimum 20 gauge solid galvanized steel or corrosion-resisting sheet steel conforming to ASTM A167, Type 304. Design and construct casing with an integral insulated structural galvanized steel frame such that exterior panels are non-load bearing.

- b. Individually removable exterior panels with standard tools. Removal must not affect the structural integrity of the unit. Furnish casings with access sections, according to paragraph AIR HANDLING UNITS, inspection doors, and access doors, all capable of opening a minimum of 90 degrees, as indicated.
- c. Insulated, fully gasketed, double-wall type inspection and access doors, of a minimum 18 gauge outer and 20 gauge inner panels made of either galvanized steel or corrosion-resisting sheet steel conforming to ASTM A167, Type 304. Provide rigid doors with heavy duty hinges and latches. Inspection doors must be a minimum 12 inches wide by 12 inches high. Access doors must be a minimum 24 inches wide, the full height of the unit casing or a minimum of 6 foot, whichever is less. Install a minimum 8 by 8 inches sealed glass window suitable for the intended application, in all access doors.
- d. Double-wall insulated type drain pan (thickness equal to exterior casing) constructed of 16 gauge corrosion resisting sheet steel conforming to ASTM A167, Type 304, conforming to ASHRAE 62.1. Construct drain pans water tight, treated to prevent corrosion, and designed for positive condensate drainage. When 2 or more cooling coils are used, with one stacked above the other, condensate from the upper coils must not flow across the face of lower coils. Provide intermediate drain pans or condensate collection channels and downspouts, as required to carry condensate to the unit drain pan out of the air stream and without moisture carryover. Construct drain pan to allow for easy visual inspection, including underneath the coil without removal of the coil and to allow complete and easy physical cleaning of the pan underneath the coil without removal of the coil. Provide coils that are individually removable from the casing.
- e. Casing insulation that conforms to NFPA 90A. Insulate single-wall casing sections handling conditioned air with not less than 1 inch thick, 1-1/2 pound density coated fibrous glass material having a thermal conductivity not greater than 0.23 Btu/hr-sf-F. Insulate double-wall casing sections handling conditioned air with not less than 2 inches of the same insulation specified for single-wall casings. Foil-faced insulation is not an acceptable substitute for use with double wall casing. Seal double wall insulation completely by inner and outer panels.
- f. Factory applied fibrous glass insulation that conforms to ASTM C1071, except that the minimum thickness and density requirements do not apply, and that meets the requirements of NFPA 90A. Make air handling unit casing insulation uniform over the entire casing. Foil-faced insulation is not an acceptable substitute for use on double-wall access doors and inspections doors and casing sections.
- g. Duct liner material, coating, and adhesive that conforms to fire-hazard requirements specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. Protect exposed insulation edges and joints where insulation panels are butted with a metal nosing strip or coat to meet erosion resistance requirements of ASTM C1071.
- h. A latched and hinged inspection door, in the fan and coil sections. Plus additional inspection doors, access doors and access sections where indicated.

2.11.1.2 Heating and Cooling Coils

Provide coils as specified in paragraph AIR SYSTEMS EQUIPMENT.

2.11.1.3 Air Filters

Provide air filters as specified in paragraph AIR SYSTEMS EQUIPMENT for types and thickness indicated.

2.11.1.4 Fans

Provide the following:

- a. Fans that are double-inlet, centrifugal type with each fan in a separate scroll. Dynamically balance fans and shafts prior to installation into air handling unit, then after it has been installed in the air handling unit, statically and dynamically balance the entire fan assembly. Mount fans on steel shafts, accurately ground and finished.
- b. Fan bearings that are sealed against dust and dirt and are precision self-aligning ball or roller type, with L50 rated bearing life at not less than 200,000 hours as defined by ABMA 9 and ABMA 11. Provide bearings that are permanently lubricated or lubricated type with lubrication fittings readily accessible at the drive side of the unit. Support bearings by structural shapes, or die formed sheet structural members, or support plates securely attached to the unit casing. Do not fasten bearings directly to the unit sheet metal casing. Furnish fans and scrolls with coating indicated.
- c. Fans that are driven by a unit-mounted, or a floor-mounted motor connected to fans by V-belt drive complete with belt guard for externally mounted motors. Furnish belt guards that are the three-sided enclosed type with solid or expanded metal face. Design belt drives for not less than a 1.3 service factor based on motor nameplate rating.
- d. Where fixed sheaves are required, the use of variable pitch sheaves is allowed during air balance, but replace them with an appropriate fixed sheave after air balance is completed. Select variable pitch sheaves to drive the fan at a speed that produces the specified capacity when set at the approximate midpoint of the sheave adjustment. Furnish motors for V-belt drives with adjustable bases, and with splashproof enclosures.
- e. Motor starters of magnetic type with weather-resistant enclosure. Select unit fan or fans to produce the required capacity at the fan static pressure with sound power level as indicated. Obtain the sound power level values according to AMCA 300, ASHRAE 68, or AHRI 260 I-P.

2.11.1.5 Access Sections and Filter/Mixing Boxes

Provide access sections where indicated and furnish with access doors as shown. Construct access sections and filter/mixing boxes in a manner identical to the remainder of the unit casing and equip with access doors. Design mixing boxes to minimize air stratification and to promote thorough mixing of the air streams.

2.11.1.6 Diffuser Sections

Furnish diffuser sections between the discharge of all housed supply fans and cooling coils of blow-through single zone units. Provide diffuser sections that are fabricated by the unit manufacturer in a manner identical to the remainder of the unit casing, designed to be airtight under positive static pressures up to 8 inches water gauge and with an access door on each side for inspection purposes. Provide a diffuser section that contains a perforated diffusion plate, fabricated of galvanized steel, Type 316 stainless steel, aluminum, or steel treated for corrosion with manufacturer's standard corrosion-resisting finish, and designed to accomplish uniform air flow across the down-stream coil while reducing the higher fan outlet velocity to within plus or minus 5 percent of the required face velocity of the downstream component.

2.12 TERMINAL UNITS

2.12.1 Room Fan-Coil Units

Provide base units that include galvanized coil casing, coil assembly drain pan outside air damper, air filter, fans, motor, fan drive, motor switch, an enclosure for cabinet models and casing for concealed models, leveling devices integral with the unit for vertical type units, and sound power levels as indicated. Obtain sound power level data or values for these units according to test procedures based on AHRI 350. Sound power values apply to units provided with factory fabricated cabinet enclosures and standard grilles. Values obtained for the standard cabinet models are acceptable for concealed models without separate test provided there is no variation between models as to the coil configuration, blowers, motor speeds, or relative arrangement of parts. Provide automatic valves and controls as specified in paragraph SUPPLEMENTAL COMPONENTS/SERVICES, subparagraph CONTROLS. Fasten each unit securely to the building structure. Provide units with capacity indicated. Provide room fan-coil units that are certified as complying with AHRI 440, and meet the requirements of UL 1995.

2.12.1.1 Enclosures

Fabricate enclosures from not lighter than 18 gauge steel, reinforced and braced. Provide enclosures with front panels that are removable and have 1/4 inch closed cell insulation or 1/2 inch thick dual density foil faced fibrous glass insulation. Make the exposed side of a high density, erosion-proof material suitable for use in air streams with velocities up to 4,500 fpm. Provide a discharge grille that is fixed and that is of such design as to properly distribute air throughout the conditioned space. Plastic discharge and return grilles are acceptable provided the plastic material is certified by the manufacturer to be classified as flame resistant according to UL 94 and the material complies with the heat deflection criteria specified in UL 1995. Provide galvanized or factory finished ferrous metal surfaces with corrosion resistant enamel, and access doors or removable panels for piping and control compartments, plus easy access for filter replacement. Provide duct discharge collar for concealed models.

2.12.1.2 Fans

Provide steel or aluminum, multiblade, centrifugal type fans. In lieu of metal, fans and scrolls could be of non-metallic materials of suitably reinforced compounds with smooth surfaces. Dynamically and statically

balance the fans. Provide accessible assemblies for maintenance. Disassemble and re-assemble by means of mechanical fastening devices and not by epoxies or cements.

2.12.1.3 Coils

Fabricate coils from not less than 3/8 inch outside diameter seamless copper tubing, with copper or aluminum fins mechanically bonded or soldered to the tubes. Provide coils with not less than 1/2 inch outside diameter flare or sweat connectors, accessory piping package with thermal connections suitable for connection to the type of control valve supplied, and manual air vent. Test coils hydrostatically at 300 psi or under water at 250 psi air pressure. Provide coils suitable for 200 psi working pressure. Make provisions for coil removal.

2.12.1.4 Drain Pans

Size and locate drain and drip pans to collect all water condensed on and dripping from any item within the unit enclosure or casing. Provide condensate drain pans designed for self-drainage to preclude the buildup of microbial slime and thermally insulated to prevent condensation and constructed of not lighter than 21 gauge type 304 stainless steel or noncorrosive ABS plastic. Provide insulation with a flame spread rating not over 25 without evidence of continued progressive combustion, a smoke developed rating no higher than 50, and of a waterproof type or coated with a waterproofing material. Design drain pans so as to allow no standing water and pitch to drain. Provide minimum 3/4 inch NPT or 5/8 inch OD drain connection in drain pan. Provide plastic or metal auxiliary drain pans to catch drips from control and piping packages, eliminating insulation of the packages; if metal, provide auxiliary pans that comply with the requirements specified above. Extend insulation at control and piping connections 1 inch minimum over the auxiliary drain pan.

2.12.1.5 Manually Operated Outside Air Dampers

Provide manually operated outside air dampers according to the arrangement indicated, and parallel airfoil type dampers of galvanized construction. Provide blades that rotate on stainless steel or nylon sleeve bearings.

2.12.1.6 Filters

Provide disposable type filter that complies with ASHRAE 52.2. Provide filters in each unit that are removable without the use of tools.

2.12.1.7 Motors

Provide motors of the permanent split-capacitor type with built-in thermal overload protection, directly connected to unit fans. Provide motor switch with two or three speeds and off, manually operated, and mounted on an identified plate inside the unit below or behind an access door or adjacent to the room thermostat. In lieu of the above fan speed control, a solid-state variable-speed controller having a minimum speed reduction of 50 percent is allowed. Provide motors with permanently-lubricated or oilable sleeve-type or combination ball and sleeve-type bearings with vibration isolating mountings suitable for continuous duty. Provide a motor power consumption, shown in watts, at the fan operating speed selected to meet the specified capacity that does not exceed the following values:

Free Discharge Motors			
Unit Capacity (cfm)	Maximum Power Consumption (Watts)		
	115V	230V	277V
200	70	110	90
300	100	110	110
400	170	150	150
600	180	210	220
800	240	240	230
1000	310	250	270
1200	440	400	440

High Static Motors	
Unit Capacity (cfm)	Maximum Power Consumption (Watts)
200	145
300	145
400	210
600	320
800	320
1000	530
1200	530

2.12.2 Coil Induction Units

Provide base unit that includes air plenums, air-discharge nozzles, air discharge grilles, recirculation grilles, water coil assembly, valve and piping package, condensate drain pan, and adjustable air-balancing dampers, plus an enclosure for cabinet models and casing for concealed models. Make each unit capable of producing not less than the capacity indicated without exceeding the indicated static pressure. Provide a sound power level as indicated with power level data or values for these units based on tests conducted according to ASA S12.51. Sound power values apply to units provided with factory fabricated cabinet enclosures and standard grilles. The values obtained for the standard cabinet models are acceptable for concealed models without separate tests, provided there is no variation between models as to coil configuration, air discharge

nozzles, air balancing dampers, or relative arrangement of parts. Provide automatic valves and controls as specified in paragraph SUPPLEMENTAL COMPONENTS/SERVICES, subparagraph CONTROLS. Secure each unit to the building structure. Provide units with capacity indicated.

2.12.2.1 Enclosures

Fabricate enclosures from not lighter than 18 gauge steel, reinforced and braced. Provide a removable front panel of enclosure and insulate when required acoustically and to prevent condensation. Provide discharge grilles that are integrally stamped and properly distribute air throughout the conditioned space. Plastic discharge and return grilles are not acceptable. Provide access doors for all piping and control compartments.

2.12.2.2 Air Plenums

Fabricate plenums from galvanized steel with interior acoustically baffled and lined with sound absorbing material to attenuate the sound power from the primary air supply to the room. Provide heat-resistant nozzles that are integral with or attached airtight to the plenum. Where coil induction units are supplied with vertical runouts, furnish a streamlined, vaned, mitered elbow transition piece for connection between the unit and ductwork. Provide an adjustable air-balancing damper in each unit.

2.12.2.3 Coils

Fabricate coils from not less than 3/8 inch outside diameter seamless copper tubing, with copper or aluminum fins, mechanically bonded or soldered to the tubes. Furnish coil connections with not less than 1/2 inch outside diameter flare or sweat connectors, accessory piping package with terminal connections suitable for connection to the type of control valve supplied, and manual air vent. Test coils hydrostatically at 300 psi or under water at 250 psi air pressure and provide coils suitable for 200 psi working pressure.

2.12.2.4 Screens

Provide easily accessible lint screens or throwaway filters for each unit.

2.12.2.5 Drain Pan

Size and locate drain and drip pans to collect condensed water dripping from any item within the unit enclosure. Provide drain pans constructed of not lighter than 21 gauge steel, galvanized after fabrication, and thermally insulated to prevent condensation. Provide insulation that has a flame spread rating not over 25 without evidence of continued progressive combustion, a smoke developed rating no higher than 50, and that is a waterproof type or coated with a waterproofing material. In lieu of the above, drain pans constructed of die-formed 22 gauge steel are allowed, formed from a single sheet and galvanized after fabrication and insulated and coated as for the 21 gauge steel material or of die-formed 21 gauge type 304 stainless steel insulated as specified above. Pitch drain pans to drain. Provide drain connection when a condensate drain system is indicated. Make connection a minimum 3/4 inch NPT or 5/8 inch OD.

2.12.3 Variable Air Volume (VAV) and Dual Duct Terminal Units

a. Provide VAV and dual duct terminal units that are the type, size, and

capacity shown, mounted in the ceiling or wall cavity, plus units that are suitable for single or dual duct system applications. Provide actuators and controls as specified in paragraph SUPPLEMENTAL COMPONENTS/SERVICES, subparagraph CONTROLS.

- b. Provide unit enclosures that are constructed of galvanized steel not lighter than 22 gauge or aluminum sheet not lighter than 18 gauge. Provide single or multiple discharge outlets as required. Units with flow limiters are not acceptable. Provide unit air volume that is factory preset and readily field adjustable without special tools. Provide reheat coils as indicated.
- c. Attach a flow chart to each unit. Base acoustic performance of the terminal units upon units tested according to AHRI 880 I-P with the calculations prepared in accordance with AHRI 885. Provide sound power level as indicated. Show discharge sound power for minimum and 1-1/2 inches water gauge inlet static pressure. Provide acoustical lining according to NFPA 90A.

2.12.3.1 Variable Volume, Single Duct Terminal Units

Provide variable volume, single duct, terminal units with a calibrated air volume sensing device, air valve or damper, actuator, and accessory relays. Provide units that control air volume to within plus or minus 5 percent of each air set point volume as determined by the thermostat with variations in inlet pressures from 3/4 to 6 inch water gauge. Provide units with an internal resistance not exceeding 0.4 inch water gauge at maximum flow range. Provide external differential pressure taps separate from the control pressure taps for air flow measurement with a 0 to 1 inch water gauge range.

2.12.3.2 Ceiling Induction Terminal Units

Provide ceiling induction unit with a calibrated primary air volume sensing device, primary air valve, induced air damper, and insulated induction tube. Arrange unit to induce air from the ceiling plenum to maintain a maximum total flow circulated to the conditioned space. Vary primary air upon demand of the room thermostat. Upon a demand for maximum cooling, provide a unit that delivers 100 percent primary air and, at minimum cooling, delivers 50 percent primary air. Provide a terminal unit capable of closing to full shut off without additional actuators or linkage changes. Provide terminals that reset primary air volume within plus or minus 5 percent determined by the thermostat regardless of upstream changes in the static pressure. Provide a minimum inlet static pressure that does not exceed 1 inch water gauge, including a maximum of 0.3 inch water gauge downstream static pressure. Provide external differential pressure taps separate from control pressure taps for primary air flow measurement with 0 to 1 inch water gauge range. Make each unit normally open upon loss of pneumatic pressure. Factory pipe actuator and accuracy controls requiring only field installation of 20 psi pneumatic main air and room thermostat.

2.12.4 Unit Ventilators

Provide unit ventilators that include an enclosure, galvanized casing, coil assembly, valve and piping package, drain pan, air filters, fan assembly, fan drive, motor, motor controller, dampers, damper operators, and sound power level as indicated. Obtain sound power level data or values for these units according to test procedures based on AHRI 350.

Sound power values apply to units provided with factory fabricated cabinet enclosures and standard grilles, when handling standard flow for which the unit air capacity is rated. Secure each unit to the building structure. Provide the unit ventilators with capacity indicated. Provide the year-round classroom type unit ventilator with automatic controls arranged to properly heat, cool, and ventilate the room. Provide automatic valves and controls as specified in paragraph SUPPLEMENTAL COMPONENTS/SERVICES, subparagraph CONTROLS. Make the sequence of control any one of the standard ANSI cycles specified in paragraph CONTROLS.

2.12.4.1 Enclosures

Fabricate enclosures from not lighter than 16 gauge galvanized steel, reinforced and braced, or all welded framework with panels to provide equivalent strength. Provide casing that is acoustically and thermally insulated internally with not less than 1/2 inch thick dual density fibrous glass insulation. Make the exposed side a high density, erosion-proof material suitable for use in air streams with velocities up to 4500 fpm. Fasten the insulation with waterproof, fire-resistant adhesive. Design front panel for easy removal by one person. Provide discharge grilles that properly distribute air throughout the conditioned space. Provide return grilles that are removable where front panel does not provide access to interior components. Plastic discharge or return grilles are not acceptable. Furnish removable panels or access doors for all piping and control compartments. Provide fan switch that is key operated or accessible through a locked access panel. Install gaskets at the back and bottom of the unit for effective air seal, as required.

2.12.4.2 Electric Resistance Heating Elements

Provide electric resistance heating elements that are of the sheathed, finned, tubular type, or of the open resistance type designed for direct exposure to the air stream. Provide heating element electrical characteristics as indicated. Where fan motor or control voltage is lower than required for the electric-resistance heating element, install a fused factory mounted and wired transformer.

2.12.4.3 Fans

Provide fans that meet the requirements as specified in paragraph AIR SYSTEMS EQUIPMENT. Provide galvanized steel or aluminum, multiblade, centrifugal type fans, dynamically and statically balanced. Equip fan housings with resilient mounted, self-aligning permanently lubricated ball bearings, sleeve bearings, or combination ball and sleeve bearings, capable of not less than 2000 hours of operation on one oiling. Provide direct-connected fans.

2.12.4.4 Coils

Provide coils that are circuited for a maximum water velocity of 8 fps without excessive pressure drop and are otherwise as specified for hot water coils in paragraph TERMINAL UNITS.

2.12.4.5 Drain Pans

Size and locate drain and drip pans to collect all condensed water dripping from any item within the unit enclosure. Provide drain pans constructed of not lighter than 18 gauge steel, galvanized after fabrication, and thermally insulated to prevent condensation. Provide

insulation that is coated with a fire-resistant waterproofing material. In lieu of the above, drain pans constructed of die-formed 20 gauge steel is allowed, formed from a single sheet and galvanized after fabrication and insulated and coated as for the 18 gauge steel material, or of die-formed 18 gauge type 304 stainless steel insulated as specified above. Pitch drain pans to drain. Furnish drain connection unless otherwise indicated. Make the minimum connection 3/4 inch NDT or 5/8 inch OD.

2.12.4.6 Filters

Disposable type rated in accordance with ASHRAE 52.2, installed upstream of coil.

2.12.4.7 Dampers

Provide an outside air proportioning damper on each unit. In addition, provide a vane to prevent excessive outside air from entering unit and to prevent blow-through of outside air through the return air grille under high wind pressures. Where outside air and recirculated air proportioning dampers are provided on the unit, an additional vane is not required. Provide face and bypass dampers for each unit to ensure constant air volume at all positions of the dampers. Furnish each unit with a factory installed control cam assembly, pneumatic motor, or electric motor to operate the face and bypass dampers and outside air damper or outside air and recirculated air dampers in the sequence as specified in paragraph SUPPLEMENTAL COMPONENTS/SERVICES, subparagraph CONTROLS.

2.12.4.8 Motors

Provide permanent split-capacitor type motors with built-in thermal overload protection and automatic reset. Mount motor on a resilient mounting, isolated from the casing and suitable for operation on electric service available. Provide a manually operated motor switch that provides for 2 or 3 speeds and off, mounted on an identified plate inside the unit below or behind an access door or adjacent to the room thermostat. In lieu of speed control, provide a solid state variable speed controller having minimum speed reduction of 50 percent.

2.12.4.9 Outside Air Intakes

Provide the manufacturer's standard design outside air intakes furnished with 1/2 inch mesh bird screen or louvers on 1/2 inch centers.

2.13 ENERGY RECOVERY DEVICES

2.13.1 Rotary Wheel

Provide unit that is a factory fabricated and tested assembly for air-to-air energy recovery by transfer of sensible heat from exhaust air to supply air stream, with device performance according to ASHRAE 84 and that delivers an energy transfer effectiveness of not less than 85 percent with cross-contamination not in excess of 1.0 percent of exhaust airflow rate at system design differential pressure, including purging sector if provided with wheel. Provide exchange media that is chemically inert, moisture-resistant, fire-retardant, laminated, nonmetallic material which complies with NFPA 90A. Isolate exhaust and supply streams by seals which are static, field adjustable, and replaceable. Equip chain drive mechanisms with ratcheting torque limiter or slip-clutch protective

device. Fabricate enclosure from galvanized steel and include provisions for maintenance access. Provide recovery control and rotation failure provisions as indicated.

2.13.2 Desiccant Wheel

Provide counterflow supply, regeneration airstreams, a rotary type dehumidifier designed for continuous operation, and extended surface type wheel structure in the axial flow direction with a geometry that allows for laminar flow over the operating range for minimum air pressure differentials. Provide the dehumidifier complete with a drive system utilizing a fractional-horsepower electric motor and speed reducer assembly driving the rotor. Include a slack-side tensioner for automatic take-up for belt-driven wheels. Provide an adsorbing type desiccant material. Apply the desiccant material to the wheel such that the entire surface is active as a desiccant and the desiccant material does not degrade or detach from the surface of the wheel which is fitted with full-face, low-friction contact seals on both sides to prevent cross leakage. Provide rotary structure that has underheat, overheat and rotation fault circuitry. Provide wheel assembly with a warranty for a minimum of five years.

2.14 FACTORY PAINTING

Factory paint new equipment, which are not of galvanized construction. Paint with a corrosion resisting paint finish according to ASTM A123/A123M or ASTM A924/A924M. Clean, phosphatize and coat internal and external ferrous metal surfaces with a paint finish which has been tested according to ASTM B117, ASTM D1654, and ASTM D3359. Submit evidence of satisfactory paint performance for a minimum of 125 hours for units to be installed indoors and 500 hours for units to be installed outdoors. Provide rating of failure at the scribe mark that is not less than 6, average creepage not greater than 1/8 inch. Provide rating of the inscribed area that is not less than 10, no failure. On units constructed of galvanized steel that have been welded, provide a final shop docket of zinc-rich protective paint on exterior surfaces of welds or welds that have burned through from the interior according to ASTM D520 Type I.

Field paint factory painting that has been damaged prior to acceptance by the Contracting Officer in compliance with the requirements of paragraph FIELD PAINTING OF MECHANICAL EQUIPMENT.

2.15 SUPPLEMENTAL COMPONENTS/SERVICES

2.15.1 Refrigerant Piping

The requirements for refrigerant piping are specified in Section 23 23 00 REFRIGERANT PIPING.

2.15.2 Condensate Drain Lines

Provide and install condensate drainage for each item of equipment that generates condensate in accordance with Section 22 00 00 PLUMBING, GENERAL PURPOSE except as modified herein.

2.15.3 Backflow Preventers

The requirements for backflow preventers are specified in Section 22 00 00 PLUMBING, GENERAL PURPOSE.

2.15.4 Insulation

The requirements for shop and field applied insulation are specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.15.5 Controls

The requirements for controls are specified in Section 23 05 93 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before performing the work.

3.2 INSTALLATION

- a. Install materials and equipment in accordance with the requirements of the contract drawings and approved manufacturer's installation instructions. Accomplish installation by workers skilled in this type of work. Perform installation so that there is no degradation of the designed fire ratings of walls, partitions, ceilings, and floors.
- b. No installation is permitted to block or otherwise impede access to any existing machine or system. Install all hinged doors to swing open a minimum of 120 degrees. Provide an area in front of all access doors that clears a minimum of 3 feet. In front of all access doors to electrical circuits, clear the area the minimum distance to energized circuits as specified in OSHA Standards, part 1910.333 (Electrical-Safety Related work practices) and an additional 3 feet.
- c. Except as otherwise indicated, install emergency switches and alarms in conspicuous locations. Mount all indicators, to include gauges, meters, and alarms in order to be easily visible by people in the area.

3.2.1 Condensate Drain Lines

Provide water seals in the condensate drain from all units. Provide a depth of each seal of 2 inches plus the number of inches, measured in water gauge, of the total static pressure rating of the unit to which the drain is connected. Provide water seals that are constructed of 2 tees and an appropriate U-bend with the open end of each tee plugged. Provide pipe cap or plug cleanouts where indicated. Connect drains indicated to connect to the sanitary waste system using an indirect waste fitting. Insulate air conditioner drain lines as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

3.2.2 Equipment and Installation

Provide frames and supports for tanks, compressors, pumps, valves, air handling units, fans, coils, dampers, and other similar items requiring supports. Floor mount or ceiling hang air handling units as indicated. Anchor and fasten as detailed. Set floor-mounted equipment on not less than 6 inch concrete pads or curbs doweled in place unless otherwise indicated. Make concrete foundations heavy enough to minimize the

intensity of the vibrations transmitted to the piping, duct work and the surrounding structure, as recommended in writing by the equipment manufacturer. In lieu of a concrete pad foundation, build a concrete pedestal block with isolators placed between the pedestal block and the floor. Make the concrete foundation or concrete pedestal block a mass not less than three times the weight of the components to be supported. Provide the lines connected to the pump mounted on pedestal blocks with flexible connectors. Submit foundation drawings as specified in paragraph DETAIL DRAWINGS. Provide concrete for foundations as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE.

3.2.3 Access Panels

Install access panels for concealed valves, vents, controls, dampers, and items requiring inspection or maintenance of sufficient size, and locate them so that the concealed items are easily serviced and maintained or completely removed and replaced. Provide access panels as specified in Section 08 31 00 ACCESS DOORS AND PANELS.

3.2.4 Flexible Duct

Install pre-insulated flexible duct in accordance with the latest printed instructions of the manufacturer to ensure a vapor tight joint. Provide hangers, when required to suspend the duct, of the type recommended by the duct manufacturer and set at the intervals recommended.

3.2.5 Metal Ductwork

Install according to SMACNA 1966 unless otherwise indicated. Install duct supports for sheet metal ductwork according to SMACNA 1966, unless otherwise specified. Do not use friction beam clamps indicated in SMACNA 1966. Anchor risers on high velocity ducts in the center of the vertical run to allow ends of riser to move due to thermal expansion. Erect supports on the risers that allow free vertical movement of the duct. Attach supports only to structural framing members and concrete slabs. Do not anchor supports to metal decking unless a means is provided and approved for preventing the anchor from puncturing the metal decking. Where supports are required between structural framing members, provide suitable intermediate metal framing. Where C-clamps are used, provide retainer clips.

3.2.5.1 Underground Ductwork

Provide PVC plastisol coated galvanized steel underground ductwork with coating on interior and exterior surfaces and watertight joints. Install ductwork as indicated, according to ACCA Manual 4 and manufacturer's instructions. Maximum burial depth is 6 feet.

3.2.5.2 Radon Exhaust Ductwork

Perforate subslab suction piping where indicated. Install PVC joints as specified in ASTM D2855.

3.2.5.3 Light Duty Corrosive Exhaust Ductwork

For light duty corrosive exhaust ductwork, use PVC plastisol coated galvanized steel with PVC coating on interior surfaces and exterior surfaces.

3.2.6 Acoustical Duct Lining

Apply lining in cut-to-size pieces attached to the interior of the duct with nonflammable fire resistant adhesive conforming to ASTM C916, Type I, NFPA 90A, UL 723, and ASTM E84. Provide top and bottom pieces that lap the side pieces and are secured with welded pins, adhered clips of metal, nylon, or high impact plastic, and speed washers or welding cup-head pins installed according to SMACNA 1966. Provide welded pins, cup-head pins, or adhered clips that do not distort the duct, burn through, nor mar the finish or the surface of the duct. Make pins and washers flush with the surfaces of the duct liner and seal all breaks and punctures of the duct liner coating with the nonflammable, fire resistant adhesive. Coat exposed edges of the liner at the duct ends and at other joints where the lining is subject to erosion with a heavy brush coat of the nonflammable, fire resistant adhesive, to prevent delamination of glass fibers. Apply duct liner to flat sheet metal prior to forming duct through the sheet metal brake. Additionally secure lining at the top and bottom surfaces of the duct by welded pins or adhered clips as specified for cut-to-size pieces. Other methods indicated in SMACNA 1966 to obtain proper installation of duct liners in sheet metal ducts, including adhesives and fasteners, are acceptable.

3.2.7 Dust Control

To prevent the accumulation of dust, debris and foreign material during construction, perform temporary dust control protection. Protect the distribution system (supply and return) with temporary seal-offs at all inlets and outlets at the end of each day's work. Keep temporary protection in place until system is ready for startup.

3.2.8 Insulation

Provide thickness and application of insulation materials for ductwork, piping, and equipment according to Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. Externally insulate outdoor air intake ducts and plenums up to the point where the outdoor air reaches the conditioning unit or up to the point where the outdoor air mixes with the return air stream.

3.2.9 Duct Test Holes

Provide holes with closures or threaded holes with plugs in ducts and plenums as indicated or where necessary for the use of pitot tube in balancing the air system. Plug insulated duct at the duct surface, patched over with insulation and then marked to indicate location of test hole if needed for future use.

3.2.10 Power Roof Ventilator Mounting

Provide foamed 1/2 inch thick, closed-cell, flexible elastomer insulation to cover width of roof curb mounting flange. Where wood nailers are used, predrill holes for fasteners.

3.2.11 Power Transmission Components Adjustment

Test V-belts and sheaves for proper alignment and tension prior to operation and after 72 hours of operation at final speed. Uniformly load belts on drive side to prevent bouncing. Make alignment of direct driven couplings to within 50 percent of manufacturer's maximum allowable range of misalignment.

3.3 EQUIPMENT PADS

Provide equipment pads to the dimensions shown or, if not shown, to conform to the shape of each piece of equipment served with a minimum 3-inch margin around the equipment and supports. Allow equipment bases and foundations, when constructed of concrete or grout, to cure a minimum of 14 calendar days before being loaded.

3.4 CUTTING AND PATCHING

Install work in such a manner and at such time that a minimum of cutting and patching of the building structure is required. Make holes in exposed locations, in or through existing floors, by drilling and smooth by sanding. Use of a jackhammer is permitted only where specifically approved. Make holes through masonry walls to accommodate sleeves with an iron pipe masonry core saw.

3.5 CLEANING

Thoroughly clean surfaces of piping and equipment that have become covered with dirt, plaster, or other material during handling and construction before such surfaces are prepared for final finish painting or are enclosed within the building structure. Before final acceptance, clean mechanical equipment, including piping, ducting, and fixtures, and free from dirt, grease, and finger marks. When the work area is in an occupied space such as office, laboratory or warehouse protect all furniture and equipment from dirt and debris. Incorporate housekeeping for field construction work which leaves all furniture and equipment in the affected area free of construction generated dust and debris; and, all floor surfaces vacuum-swept clean.

3.6 PENETRATIONS

Provide sleeves and prepared openings for duct mains, branches, and other penetrating items, and install during the construction of the surface to be penetrated. Cut sleeves flush with each surface. Place sleeves for round duct 15 inches and smaller. Build framed, prepared openings for round duct larger than 15 inches and square, rectangular or oval ducts. Sleeves and framed openings are also required where grilles, registers, and diffusers are installed at the openings. Provide one inch clearance between penetrating and penetrated surfaces except at grilles, registers, and diffusers. Pack spaces between sleeve or opening and duct or duct insulation with mineral fiber conforming with ASTM C553, Type 1, Class B-2.

3.6.1 Sleeves

Fabricate sleeves, except as otherwise specified or indicated, from 20 gauge thick mill galvanized sheet metal. Where sleeves are installed in bearing walls or partitions, provide black steel pipe conforming with ASTM A53/A53M, Schedule 20.

3.6.2 Framed Prepared Openings

Fabricate framed prepared openings from 20 gauge galvanized steel, unless otherwise indicated.

3.6.3 Insulation

Provide duct insulation in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS continuous through sleeves and prepared openings except firewall penetrations. Terminate duct insulation at fire dampers and flexible connections. For duct handling air at or below 60 degrees F, provide insulation continuous over the damper collar and retaining angle of fire dampers, which are exposed to unconditioned air.

3.6.4 Closure Collars

Provide closure collars of a minimum 4 inches wide, unless otherwise indicated, for exposed ducts and items on each side of penetrated surface, except where equipment is installed. Install collar tight against the surface and fit snugly around the duct or insulation. Grind sharp edges smooth to prevent damage to penetrating surface. Fabricate collars for round ducts 15 inches in diameter or less from 20 gauge galvanized steel. Fabricate collars for square and rectangular ducts, or round ducts with minimum dimension over 15 inches from 18 gauge galvanized steel. Fabricate collars for square and rectangular ducts with a maximum side of 15 inches or less from 20 gauge galvanized steel. Install collars with fasteners a maximum of 6 inches on center. Attach to collars a minimum of 4 fasteners where the opening is 12 inches in diameter or less, and a minimum of 8 fasteners where the opening is 20 inches in diameter or less.

3.6.5 Firestopping

Where ducts pass through fire-rated walls, fire partitions, and fire rated chase walls, seal the penetration with fire stopping materials as specified in Section 07 84 00 FIRESTOPPING.

3.7 FIELD PAINTING OF MECHANICAL EQUIPMENT

Clean, pretreat, prime and paint metal surfaces; except aluminum surfaces need not be painted. Apply coatings to clean dry surfaces. Clean the surfaces to remove dust, dirt, rust, oil and grease by wire brushing and solvent degreasing prior to application of paint, except clean to bare metal on metal surfaces subject to temperatures in excess of 120 degrees F. Where more than one coat of paint is specified, apply the second coat after the preceding coat is thoroughly dry. Lightly sand damaged painting and retouch before applying the succeeding coat. Provide aluminum or light gray finish coat.

3.7.1 Temperatures less than 120 degrees F

Immediately after cleaning, apply one coat of pretreatment primer applied to a minimum dry film thickness of 0.3 mil, one coat of primer applied to a minimum dry film thickness of one mil; and two coats of enamel applied to a minimum dry film thickness of one mil per coat to metal surfaces subject to temperatures less than 120 degrees F.

3.7.2 Temperatures between 120 and 400 degrees F

Apply two coats of 400 degrees F heat-resisting enamel applied to a total minimum thickness of two mils to metal surfaces subject to temperatures between 120 and 400 degrees F.

3.7.3 Temperatures greater than 400 degrees F

Apply two coats of 315 degrees C 600 degrees F heat-resisting paint applied to a total minimum dry film thickness of two mils to metal surfaces subject to temperatures greater than 400 degrees F.

3.7.4 Finish Painting

The requirements for finish painting of items only primed at the factory, and surfaces not specifically noted otherwise, are specified in Section 09 90 00 PAINTS AND COATINGS.

3.7.5 Color Coding Scheme for Locating Hidden Utility Components

Use scheme in buildings having suspended grid ceilings. Provide color coding scheme that identifies points of access for maintenance and operation of components and equipment that are not visible from the finished space and are accessible from the ceiling grid, consisting of a color code board and colored metal disks. Make each colored metal disk approximately 3/8 inch diameter and secure to removable ceiling panels with fasteners. Insert each fastener into the ceiling panel so as to be concealed from view. Provide fasteners that are manually removable without the use of tools and that do not separate from the ceiling panels when the panels are dropped from ceiling height. Make installation of colored metal disks follow completion of the finished surface on which the disks are to be fastened. Provide color code board that is approximately 3 foot wide, 30 inches high, and 1/2 inches thick. Make the board of wood fiberboard and frame under glass or 1/16 inch transparent plastic cover. Make the color code symbols approximately 3/4 inch in diameter and the related lettering in 1/2 inch high capital letters. Mount the color code board in the mechanical or equipment room. Make the color code system as indicated below:

Color	System	Item	Location

3.8 IDENTIFICATION SYSTEMS

Provide identification tags made of brass, engraved laminated plastic, or engraved anodized aluminum, indicating service and item number on all valves and dampers. Provide tags that are 1-3/8 inch minimum diameter with stamped or engraved markings. Make indentations black for reading clarity. Attach tags to valves with No. 12 AWG 0.0808-inch diameter corrosion-resistant steel wire, copper wire, chrome-plated beaded chain or plastic straps designed for that purpose.

3.9 DUCTWORK LEAK TEST

Perform ductwork leak test for the entire air distribution and exhaust system, including fans, coils, filters, etc. Provide test procedure, apparatus, and report that conform to SMACNA 1972 CD. The maximum allowable leakage rate is cfm. Complete ductwork leak test with satisfactory results prior to applying insulation to ductwork exterior or concealing ductwork.

3.10 DAMPER ACCEPTANCE TEST

Submit the proposed schedule, at least 2 weeks prior to the start of test. Operate all fire dampers and smoke dampers under normal operating conditions, prior to the occupancy of a building to determine that they function properly. Test each fire damper equipped with fusible link by having the fusible link cut in place. Test dynamic fire dampers with the air handling and distribution system running. Reset all fire dampers with the fusible links replaced after acceptance testing. To ensure optimum operation and performance, install the damper so it is square and free from racking.

3.11 TESTING, ADJUSTING, AND BALANCING

The requirements for testing, adjusting, and balancing are specified in Section 23 05 93 TESTING, ADJUSTING AND BALANCING FOR HVAC. Begin testing, adjusting, and balancing only when the air supply and distribution, including controls, has been completed, with the exception of performance tests.

3.12 PERFORMANCE TESTS

Conduct performance tests as required in Section 23 05 93 Testing, Adjusting and Balancing for HVAC and Section 23 09 00 Instrumentation and Control for HVAC.

3.13 CLEANING AND ADJUSTING

Provide a temporary bypass for water coils to prevent flushing water from passing through coils. Inside of air terminal units, thoroughly clean ducts, plenums, and casing of debris and blow free of small particles of rubbish and dust and then vacuum clean before installing outlet faces. Wipe equipment clean, with no traces of oil, dust, dirt, or paint spots. Provide temporary filters prior to startup of all fans that are operated during construction, and provide new filters after all construction dirt has been removed from the building, and the ducts, plenums, casings, and other items specified have been vacuum cleaned. Perform and document that proper "Indoor Air Quality During Construction" procedures have been followed; provide documentation showing that after construction ends, and prior to occupancy, new filters were provided and installed. Maintain system in this clean condition until final acceptance. Properly lubricate bearings with oil or grease as recommended by the manufacturer. Tighten belts to proper tension. Adjust control valves and other miscellaneous equipment requiring adjustment to setting indicated or directed. Adjust fans to the speed indicated by the manufacturer to meet specified conditions. Maintain all equipment installed under the contract until close out documentation is received, the project is completed and the building has been documented as beneficially occupied.

3.14 OPERATION AND MAINTENANCE

3.14.1 Operation and Maintenance Manuals

Submit six manuals at least 2 weeks prior to field training. Submit data complying with the requirements specified in Section 01 78 23 OPERATION AND MAINTENANCE DATA. Submit Data Package 3 for the items/units listed under SD-10 Operation and Maintenance Data

3.14.2 Operation And Maintenance Training

Conduct a training course for the members of the operating staff as designated by the Contracting Officer. Make the training period consist of a total of 4 hours of normal working time and start it after all work specified herein is functionally completed and the Performance Tests have been approved. Conduct field instruction that covers all of the items contained in the Operation and Maintenance Manuals as well as demonstrations of routine maintenance operations. Submit the proposed On-site Training schedule concurrently with the Operation and Maintenance Manuals and at least 14 days prior to conducting the training course.

-- End of Section --

SECTION 23 31 13.00 40

METAL DUCTS

08/22

PART 1 GENERAL

Section 23 30 00 HVAC AIR DISTRIBUTION apply to work specified in this section.

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 325 (2017) Steel Construction Manual
AISC 360 (2016) Specification for Structural Steel Buildings

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE EQUIP IP HDBK (2012) Handbook, HVAC Systems and Equipment (IP Edition)
ASHRAE FUN IP (2021) Fundamentals Handbook, I-P Edition

AMERICAN WELDING SOCIETY (AWS)

AWS A5.8/A5.8M (2019) Specification for Filler Metals for Brazing and Braze Welding

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M (2019) Standard Specification for Carbon Structural Steel
ASTM A123/A123M (2017) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A653/A653M (2023) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A924/A924M (2022a) Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process
ASTM C1071 (2019) Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)

ASTM D257	(2014) Standard Test Methods for D-C Resistance or Conductance of Insulating Materials
ASTM E477	(2020) Standard Test Method for Laboratory Measurements of Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers
NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)	
NFPA 90A	(2024) Standard for the Installation of Air Conditioning and Ventilating Systems
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)	
NIST HB 150	(2016) National Voluntary Laboratory Accreditation Program Procedures and General Requirements
NIST HB 150-8	(2018) NVLAP Acoustical Testing Services
SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)	
SMACNA 1966	(2020) HVAC Duct Construction Standards Metal and Flexible, 4th Edition
SMACNA 1987	(2006) HVAC Duct Systems Inspection Guide, 3rd Edition
SOCIETY FOR PROTECTIVE COATINGS (SSPC)	
SSPC Painting Manual	(2002) Good Painting Practice, Steel Structures Painting Manual, Volume 1
SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)	
SAE AMS 2480	(2009; Rev H) Phosphate Treatment, Paint, Base
UNDERWRITERS LABORATORIES (UL)	
UL 181	(2013; Reprint Dec 2021) UL Standard for Safety Factory-Made Air Ducts and Air Connectors
UL 555	(2006; Reprint Aug 2016) UL Standard for Safety Fire Dampers

1.2 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material, Equipment, and Fixture Lists; G

Records of Existing Conditions; G

SD-02 Shop Drawings

Connection Diagrams; G

Offset Fitting Configurations; G

SD-03 Product Data

Equipment and Performance Data

Galvanized Steel Ductwork Materials; G

Brazing Materials

Mill-Rolled Reinforcing and Supporting Materials

Round Sheet Metal Duct Fittings; G

Round, High-Pressure, Double-Wall Sheet Metal Ducts; G

Turning Vanes; G

Sound Attenuators; G

Flexible Connectors; G

Flexible Duct Materials

Power-Operated Dampers; G

Fire Dampers and Wall Collars; G

Gravity Backdraft and Relief Dampers; G

Manual Volume Dampers; G

SD-05 Design Data

Design Analysis and Calculations; G

SD-06 Test Reports

Ductwork Leakage Tests; G

SD-07 Certificates

Listing of Product Installations

Galvanized Steel Ductwork Materials

Brazing Materials

Mill-Rolled Reinforcing and Supporting Materials

Round Sheet Metal Duct Fittings

Round, High-Pressure, Double-Wall Sheet Metal Ducts

Turning Vanes

Dampers

Sound Attenuators

Flexible Connectors

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G

Power Operated Dampers; G

Fire Dampers and Wall Collars; G

SD-11 Closeout Submittals

Record Drawings; G

1.3 QUALITY CONTROL

When furnishing the listing of product installations for medium and high pressure ductwork systems include identification of at least 5 units, similar to those proposed for use, that have been in successful service for a minimum period of 5 years. Include purchaser, address of installation, service organization, and date of installation.

PART 2 PRODUCTS

Include the manufacturer's style or catalog numbers, specification and drawing reference numbers, warranty information, and fabrication site information within material, equipment, and fixture lists.

2.1 SYSTEM DESCRIPTION

Provide low-pressure systems ductwork and plenums where maximum air velocity is 2,000-feet per minute (fpm) and maximum static pressure is 2-inches water gage (wg), positive or negative.

Submit connection diagrams for low pressure ductwork systems indicating the relation and connection of devices and apparatus by showing the general physical layout of all controls, the interconnection of one system (or portion of system) with another, and internal tubing, wiring, and other devices.

High velocity systems ductwork encompass systems where:

- a. Minimum air velocity exceeds 2,000-feet per minute (fpm) or static pressure exceeds 2-inches water gage (wg).
- b. Medium static pressure ranges from over 2-inches wg through 3-inches wg, positive or negative, or over 3-inches wg through 6-inches wg positive.

d. Do not use rigid fibrous-glass ductwork.

2.1.1 Design Requirements

Submit records of existing conditions including the results of a survey consisting of work area conditions, and features of existing structures and facilities within and adjacent to the jobsite.

Submit equipment and performance data for medium and high pressure ductwork systems consisting of use life, system functional flows, safety features, and mechanical automated details. Submit test response and performance characteristics curves for certified equipment.

Submit design analysis and calculations for ductwork systems indicating the manufacturer's recommended air velocities, maximum static pressure, and temperature calculations.

2.2 COMPONENTS

2.2.1 Round Sheet Metal Duct Fittings

Submit offset fitting configurations for approval. Shop fabricate fittings.

2.2.1.1 Fittings Construction

Manufacture as separate fittings, not as tap collars welded or brazed into duct sections.

Provide two-piece type miter elbows for angles less than 31 degrees, three-piece type for angles 31 through 60 degrees, and five-piece type for angles 61 through 90 degrees. Ensure centerline radius of elbows is 1-1/2 times fitting cross section diameter.

Provide conical type crosses, increasers, reducers, reducing tees, and 90-degree tees.

Ensure cutouts in fitting body are equal to branch tap dimension or, where smaller, excess material is flared and rolled into smooth radius nozzle configuration.

2.2.2 Round, High-Pressure, Double-Wall Sheet Metal Ducts

Shop fabricate ducts and fittings.

Construction comprises of an airtight, vapor barrier, outer pressure shell, a 1 inch insulation layer, and a metal inner liner that completely covers the insulation throughout the system.

Provide insulation conforming to NFPA 90A and ASTM C1071 for thermal conductivity in accordance with ASTM D257.

2.2.3 Reinforcement

Support inner liners of both duct and fittings by metal spacers welded in position to maintain spacing and concentricity.

2.2.4 Fittings

Make divided flow fittings as separate fittings, not tap collars into duct sections, with the following construction requirements:

- a. Sound, airtight, continuous welds at intersection of fitting body and tap
- b. Tap liner securely welded to inner liner, with weld spacing not to exceed 3-inches.
- c. Pack insulation around the branch tap area for complete cavity filling.
- d. Carefully fit branch connection to cutout openings in inner liner without spaces for air erosion of insulation and without sharp projections that cause noise and airflow disturbance.

Continuously braze seams in the pressure shell of fittings. Protect galvanized areas that have been damaged by welding with manufacturer's standard corrosion-resistant coating.

Construct two-piece type elbows for angles through 35 degrees, three-piece type for angles 36 through 71 degrees, and five-piece type for angles 72 through 90 degrees.

Provide conical type crosses, increasers, reducers, reducing tees, and 90-degree tees.

2.2.5 Turning Vanes

Provide double-wall type turning vanes, commercially manufactured for high-velocity system service.

2.2.6 Dampers

Construct low pressure drop, high-velocity manual volume dampers, and high-velocity fire dampers in accordance with ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

2.2.7 Sound Attenuators

Provide sound attenuators.

Ensure the pressure drop at the rated flow does not exceed ratings in accordance with ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966 or design criteria.

Ensure the sound attenuators is airtight when operating under an internal pressure of 0.37 pounds per square inch. Provide an air-side surface capable of withstanding air velocities of 10,000-feet per minute without any particulate matter leaving the trap and being carried downstream.

2.2.7.1 Attenuation

Factory fabricate sound attenuators. Confirm pressure drop measurements in accordance with ASHRAE EQUIP IP HDBK, Chapter 18. Units shall be tested in accordance with ASTM E477 silencer test standard in aero-acoustical test facility which is NVLAP accredited for ASTM E477 standard. Submit copy of laboratory's NVLAP accreditation certificate on

dynamic insertion loss, self-noise power levels, and aerodynamic performance according to the requirements of NIST HB 150 and NIST HB 150-8. Conduct tests with standard metal inlet and outlet connections under indicated capacity flow.

Ensure attenuation is in accordance with ASHRAE FUN IP. Include a graphic system noise spectrum certification indicating proposed fan sound power level. Attenuation of ducting system proposed for installation is based on ASHRAE FUN IP for bends, branches, and other duct system construction noise criteria curve.

Reduce fan-rated sound-power level to not less than 65 decibels in the 250-hertz third octave band when measured at the sound attenuation discharge end.

2.2.7.2 Construction of Sound Attenuators

Provide double-metal walled, rectangular sound attenuators. Provide mill-galvanized sheet metal steel with commercial weight of zinc, conforming to ASTM A653/A653M. Exterior metal acts as a vapor barrier. Metal thickness is not less than that required for the pressure service, in accordance with ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966, but not less than 22-gage. Cover absorbing material, on the sound-impinging side, with formed perforated mill-galvanized steel of not less than 24-gage. Ensure all exterior sheet joints are continuously welded, or construct with locksets filled with neoprene mastic prior to forming.

Spot weld interior surfaces not more than 3-inches on center. Ensure all connections to duct transitions are flanged with through-bolted 1/8-inch by 1-inch continuous rubber gasketing. Provide vibration isolated trapeze type supports.

Provide fibrous glass absorption material. Ensure surfaces exposed to airstream are neoprene coated or protected with woven fibrous-glass cloth conforming to ASTM C1071. Ensure the total compressed thickness gives the required attenuation, and thermal insulation to preclude condensation on exterior surface under normal operating conditions. Compressed material density is approximately 4.5 pounds per cubic foot. Select materials conforming to fire hazard requirements of NFPA 90A.

2.2.8 Flexible Connectors for Sheet Metal

Use UL listed connectors, 30-ounce per square yard, waterproof, fire-retardant, airtight, woven fibrous-glass cloth, double coated with neoprene. Clear width, not including clamping section, is 6 to 8-inches.

Provide leaded vinyl sheets as a second layer for sound attenuation. Ensure leaded vinyl is not less than 0.055-inch thick, weighing not less than 0.87 pound per square foot, and capable of approximately 10-decibel attenuation in the 10- to 10,000-hertz range.

2.2.9 Duct Hangers

For duct hangers in contact with galvanized duct surfaces, provide galvanized steel painted with inorganic zinc.

2.2.10 Mill-Rolled Reinforcing and Supporting Materials

Provide mill-rolled structural steel conforming to ASTM A36/A36M. Whenever in contact with sheet metal ducting, provide galvanized steel in accordance with ASTM A123/A123M.

In lieu of mill-rolled structural steel, submit equivalent strength, proprietary-design, rolled-steel structural support systems for approval.

2.2.11 Flexible Duct Materials

Ensure flexible duct connectors comply with NFPA 90A, and conform with UL 181, Class 1 material.

Provide carbon steel zinc-coated ASTM A123/A123M metal duct; bendable through 180 degrees without damage, with an inside bend radius not greater than one-half the diameter of duct.

2.2.12 Manual Volume Dampers

Conform to SMACNA 1966 for volume damper construction.

Equip dampers with an indicating quadrant regulator with a locking feature externally located and easily accessible for adjustment and standoff brackets to allow mounting outside external insulation. Where damper rod lengths exceed 30-inches, provide a regulator at each end of damper shaft.

2.2.12.1 Damper Construction

Provide all damper shafts with two-end bearings.

Ensure splitter damper is 22 -gage sheet metal. Hinges are 1/8-inch thick door type.

Provide a full length damper shaft and extend it beyond the damper blade. use a 3/8 -inch square shaft for damper lengths up to 20 -inches and a 1/2 -inch square shaft for damper lengths 20 -inches and larger. Where necessary to prevent damper vibration or slippage, provide adjustable support rods with locking provisions external to duct at damper blade end.

Provide dampers in ducts having a width perpendicular to the axis of the damper that is greater than 12 -inches of multiblade type having a substantial frame with blades fabricated of 16 -gage metal. Provide blades not exceeding 10 -inches in width and 48 -inches in length, pinned to 1/2 -inch diameter shafts. Ensure dampers greater than 48 -inches in width are made in two or more sections with intermediate mullions, each section being mechanically interlocked with the adjoining section or sections. Provide blades with oil-impregnated sintered bronze bearings and connect so that adjoining blades rotate in opposite directions.

2.2.13 Gravity Backdraft and Relief Dampers

Construct frames of not less than 1-1/2- by 4-inch reinforced 16-gage galvanized carbon steel. Solidly secure frames and mullions in place and seal with elastomer caulking against air bypass.

Provide shaft bearings with oil-impregnated bronze.

Equip counterbalanced dampers with fixed or adjustable counterbalancing

weights.

Gravity backdraft dampers may be equipment manufacturer's standard construction in sizes 18 by 18-inch or smaller, when furnished integral with air moving equipment.

2.2.13.1 Blade Construction

Maximum blade width is 9 inches, and maximum blade length is 36 inches. Blade material is 16-gage galvanized steel. Provide blades with mechanically retained seals and 90-degree limit stops.

Blades linked together for relief service dampers are to open not less than 30 degrees on 0.05-inch wg differential pressure.

2.2.14 Power-Operated Dampers

2.2.15 Fire Dampers and Wall Collars

Ensure fire damper locations are in accordance with NFPA 90A.

Provide fire dampers in ductwork at firewall barriers.

Construct and label fire dampers in accordance with UL 555 to provide damper and mounting fire-resistance that equals or exceeds fire-resistance of the construction in which installed. For link loads in excess of 20 pounds, provide UL-approved quartzoid links.

Construct wall collars in accordance with UL 555.

2.3 MATERIALS

2.3.1 Galvanized Steel Ductwork Materials

Provide hot-dip galvanized carbon steel ductwork sheet metal of lock-forming quality, with regular spangle-type zinc coating, conforming to ASTM A924/A924M and ASTM A653/A653M, Designation G90. Treat duct surfaces to be painted by annealing.

Conform to ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966 for sheet metal gages and reinforcement thickness.

Low pressure ductwork minimum thicknesses are:

MINIMUM SHEET METAL THICKNESS	
<u>DUCT WIDTH</u> INCHES	<u>GAGE</u>
0-12	26
13-30	24
31-60	22

2.3.2 Brazing Materials

Provide silicon bronze brazing materials conforming to AWS A5.8/A5.8M.

2.3.3 Mill-Rolled Reinforcing and Supporting Materials

Conform to ASTM A36/A36M for mill-rolled structural steel. Wherever in contact with sheet metal ducting, galvanize to conforming with ASTM A123/A123M SSPC Painting Manual.

In lieu of mill-rolled structural steel, submit for approval, equivalent strength, proprietary design, rolled-steel structural support systems.

2.3.4 Manufactured Round Ductwork (Positive Pressure)

Duct and fittings suitable to positive 10 inches WG. Ducts shall be machine formed round and/or flat oval as shown on drawings, constructed of G90 galvanized steel. Use spiral lockseam construction. Longitudinal seam construction may be used for ductwork over 80 inches diameter with minimum 16 ga. Use fittings as indicated on drawings, as specified, and as required in accordance with manufacturer's published data.

Unless otherwise indicated, connection shall be slip type with minimum 2 inches insertion length or flanged joint in accordance with manufacturer's recommendations. When flange joints are required, use Van Stone angle rings welded to duct. Internal bracing is not allowed.

PART 3 EXECUTION

3.1 PREPARATION

For sheet metal surfaces to be painted, and surfaces to which adhesives are to be applied, clean surface of oil, grease, and deleterious substances.

Ensure strength is adequate to prevent failure under service pressure or vacuum created by fast closure of duct devices. Provide leaktight, automatic relief devices.

3.1.1 Construction Standards

Provide sheet metal construction in accordance with the recommendations for best practices in ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32, SMACNA 1966, and NFPA 90A.

Design and fabricate supplementary steel in accordance with AISC 360 and AISC 325.

Where construction methods for certain items are not described in the referenced standards or herein, perform the work in accordance with recommendations for best practice defined in ASHRAE EQUIP IP HDBK.

3.2 INSTALLATION

Fabricate an airtight system. Include reinforcements, bracing, supports, framing, gasketing, sealing, and fastening to provide rigid construction and freedom from vibration, airflow-induced motion and noise, and excessive deflection at specified maximum system air pressure and velocity.

Provide offsets and transformations as required to avoid interference with the building construction, piping, or equipment.

Make plenum anchorage provisions, sheet metal joints, and other areas

airtight and watertight by caulking, mating galvanized steel and concrete surfaces with a two-component elastomer.

3.2.1 Jointing

Enclose dampers located behind architectural intake or exhaust louvers by a rigid sheet metal collar and sealed to building construction with elastomers for complete air tightness.

Provide outside air-intake ducts and plenums made from sheet metal with soldered watertight joints.

3.2.2 Ducts

Wherever ducts pass through firewalls or through walls or floors dividing conditioned spaces from unconditioned spaces, provide a flanged segment in that surface during surface construction.

Where interiors of ducting may be viewed through air diffusion devices, construct the viewed interior with sheet metal and paint flat black.

3.2.2.1 Ductwork Cleaning Provisions

Protect open ducting from construction dust and debris in a manner approved by the Contracting Officer. Clean dirty assembled ducting by subjecting all main and branch interior surfaces to airstreams moving at velocities two times specified working velocities, at static pressures within maximum ratings. This may be accomplished by: filter-equipped portable blowers which remain the Contractor's property; wheel-mounted, compressed-air operated perimeter lances which direct the compressed air and which are pulled in the direction of normal airflow; or other means approved by the Contracting Officer. Use water- and oil- free compressed air for cleaning ducting. After construction is complete, and prior to acceptance of the work, remove construction dust and debris from exterior surfaces. Clean in conformance with SMACNA 1987.

3.3 APPLICATION

3.3.1 Low Pressure Sheet Metal Ducts

Weld angle iron frames at corners and ends, whenever possible. Rivet or weld angle iron reinforcements to ducts not more than 6-inches on center, with not less than two points of attachment. Spot welding, where used, is 3-inches on center.

Seal standard seam joints with an elastomer compound to comply with SMACNA 1966 Seal Class A, B or C as applicable.

Limit crossbreaking to 4-feet and provide on all ducts 8-inches wide and wider. Provide bead reinforcement in lieu of crossbreaking where panel popping may occur. Where rigid insulation is applied, crossbreaking is not required.

3.3.1.1 Longitudinal Duct Seams

Provide Pittsburgh lock corner seams.

3.3.1.2 Joints and Gaskets

Bolt companion angle flanges together with 1/4 -inch diameter bolts and nuts spaced 6 -inches on center. Gasket flanged joints with neoprene full-face gaskets 1/8 -inch thick, with Shore A 40 durometer hardness. Use one piece gaskets, vulcanized at joints.

3.3.1.3 Flexible Duct Joints

Between flexible duct without sheet metal collars and round metal ductwork connections make joints by trimming the ends, coating the inside of the flexible duct for a distance equal to depth of insertion with elastomer caulk, and by securing with sheet metal screws or binding with a strap clamp.

3.3.1.4 Square Elbows

Provide single-vane duct turns in accordance with SMACNA 1966, use on ducts 12 inches in width and narrower.

3.3.1.5 Radius Elbows

Conform to SMACNA 1966 for radius elbows. Provide an inside radius equal to the width of the duct. Where installation conditions preclude use of standard elbows, the inside radius may be reduced to a minimum of 0.25 times duct width. Install turning vanes in accordance with the following schedule.

WIDTH OF ELBOWS INCHES	RADIUS OF TURNING VANES IN PERCENT OF DUCT WIDTH		
	<u>VANE NO. 1</u>	<u>VANE NO. 2</u>	<u>VANE NO. 3</u>
Up to 16	56	--	--
17 to 48	43	73	--
49 and over	37	55	83

Where two elbows are placed together in the same plane for ducts 30-inches wide and larger, continue the guide vanes through both elbows rather than spaced in accordance with above schedule.

3.3.1.6 Outlets, Inlets, and Duct Branches

Install branches, inlets, and outlets so that air turbulence is reduced to a minimum and air volume properly apportioned. Install adjustable splitter dampers at all supply junctions to permit adjustment of the amount of air entering the branch. Wherever an air-diffusion device is shown as being installed on the side, top, or bottom of a duct, and whenever a branch take-off is not of the splitter type; provide a commercially manufactured 45 degree side-take-off (STO) fitting with manual volume damper to allow adjustment of the air quantity and to provide an even flow of air across the device or duct it services.

Where a duct branch is to handle more than 25 percent of the air handled by the duct main, use a complete 90-degree increasing elbow with an inside radius of 0.75 times branch duct width. Size of the leading end of the increasing elbow within the main duct with the same ratio to the main duct size as the ratio of the related air quantities handled.

Where a duct branch is to handle 25 percent or less of the air handled by the duct main, construct the branch connection with a 45 degree side take-off entry in accordance with SMACNA 1966.

3.3.1.7 Duct Transitions

Where the shape of a duct changes, ensure the angle of the side of the transition piece does not exceed 15 degrees from the straight run of duct connected thereto.

Where equipment is installed in ductwork, ensure the angle of the side of the transition piece from the straight run of duct connected thereto does not exceed 15 degrees on the upstream side of the equipment and 22-1/2 degrees on the downstream side of the equipment.

3.3.1.8 Branch Connections

Construct radius tap-ins in accordance with SMACNA 1966.

3.3.1.9 Access Openings

Construct access door in accordance with SMACNA 1966, except that sliding doors may be used only for special conditions upon prior approval. Provide double-panel type doors.

Install access doors and panels in ductwork at controls or at any item requiring periodic inspection, adjustment, maintenance, or cleaning , and every 20-feet for indoor air quality housekeeping purposes.

Minimum access opening size is 12 by 18 -inches, unless precluded by duct dimensions or otherwise indicated.

Make airtight access doors that leak by adding or replacing hinges and latches or by construction of new doors adequately reinforced, hinged, and latched.

3.3.1.10 Plenum Construction

Provide intake and discharge plenum companion angle joints with the following minimum thickness of materials:

<u>LONGEST ANGLES SIDE INCHES</u>	<u>SHEET METAL USS GAGE ALL SIDES</u>	<u>COMPANION ANGLES INCHES</u>	<u>REINFORCEMENT 24 INCHES ON CENTER MAXIMUM</u>
To 48	20	1-1/2 by 1-1/2 by 1/8	1-1/2 by 1-1/2 by 1/8
49 to 84	18	2 by 2 by 1/8	2 by 2 by 3/16
85 to 120	16	2 by 2 by 1/8	2 by 2 by 1/8
121 and larger	14	2 by 2 by 3/16	2 by 2 by 3/16

At the floor line and other points where plenums join masonry construction, bolt panels 12 -inches on center to 2- by 2- by 3/16 -inch thick hot-dip galvanized steel angle that has been secured to the masonry with masonry anchors and bolts 24-inches on center and caulked tight to the masonry.

Anchor panels to curbing with hot-dip galvanized steel angle iron of a size not less than 2- by 2- by 3/16 -inch thick. Concrete curbing includes angle iron nosing with welded studs for the anchoring of panels. Level nosing at curb height within plus or minus 1/16 -inch.

Weld and grind miter corners for angle iron and channel iron.

3.3.1.11 Plenum Door Construction

Construct plenum access doors in accordance with SMACNA 1966 except that access doors smaller than man-access doors have door openings framed with angle iron that is one commercial size smaller than the specified panel reinforcement.

Ensure man-access door size conforms to SMACNA 1966 and paragraph ACCESS OPENINGS. Insulated and uninsulated construction is per SMACNA 1966. Frame door openings with channel iron. Frame doors with angle iron. Size channel iron and angle iron approximately the same size as specified panel reinforcement. Provide exterior door skin 16 gage. Fabricate latches from steel with hinges at least 4 -inches long, and bolts at least 3/8 -inch diameter.

3.3.1.12 Manual Volume Dampers

Provide balancing dampers of the splitter, butterfly, or multilouver type, to balance each respective main and branch duct.

For dampers regulated through ceilings provide a regulator concealed in a box mounted in the ceiling, with a cover finish aesthetically compatible with ceiling surface. Where ceiling is of removable construction, set regulators above the ceiling, and mark the location on ceiling in a manner acceptable to the Contracting Officer.

3.3.1.13 Flexible Connectors for Sheet Metal

Connect air handling equipment, ducts crossing building expansion joints, and fan inlets and outlets to upstream and downstream components by treated woven-cloth connectors.

Install connectors only after system fans are operative, and vibration isolation mountings have been adjusted. When system fans are operating, ensure connectors are free of wrinkles caused by misalignment or fan reaction. Width of surface is curvilinear.

3.3.2 Rectangular Sheet Metal Ducts

3.3.2.1 Medium-Pressure Gages, Joints, and Reinforcement

Ensure minimum sheet metal gages, joints, and reinforcements between joints are in accordance with ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

Ensure sheet metal minimum thickness, transverse reinforcement between joints, and joints of ducts are in accordance with the following:

LONGEST SIDE (INCHES)	SHEET METAL GAGE ALL SIDES	COMPANION ANGLE (INCHES)	REINFORCEMENT ANGLES 24 INCHES ON CENTER MAXIMUM (BACK TO BACK)
97 to 108	16	2 by 2 by 1/8, two tie rods along angle	Two 2 by 2 by 1/8, two tie rods along angle
109 to 132	16	2 by 2 by 3/16, two tie rods along angle	Two 2 by 2 by 3/16, two tie rods along angle
133 and longer	14	2 by 2 by 3/16, with tie rods every 48 inches	Two 2 by 2 by 3/16, with tie rods every 48 inches

3.3.2.2 Medium- And High-Pressure Branches, Inlets, Outlets

Install branches, inlets, and outlets to minimize air turbulence and to ensure proper airflow.

Install dampers so that the amount of air entering duct mains is adjustable.

Provide commercially manufactured air extractors to allow adjustment of the air quantity and to provide an even flow of air across the device or duct served.

3.3.2.3 Duct Branch Transition

Where a duct branch handles over 25 percent of the air transported by the duct main, use a complete 90-degree increasing elbow, with an inside radius of 0.75 times duct branch width. Ensure the size of the trailing end of the increasing elbow within the main duct has the same ratio to the main duct size as the ratio of the relative air quantities handled.

Where a duct branch is to handle 25 percent or less of the air handled by the duct main, provide a branch connection with an inside radius of 0.75 times branch duct width, a minimum arc length of 45 degrees, and an outside radius of 1.75 times duct branch width. Place arc tangent to duct main.

3.3.2.4 High-Pressure Gages, Joints, and Reinforcement

Ensure sheet metal minimum thickness, joints, and reinforcement between joints are in accordance with ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

Use the following types of ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966 joints and seams:

Transverse Joints:

- a. Welded flange joint with angle
- b. Companion angle flanged joint

Longitudinal Seams:

- a. Approved lock seams, back brazed, or continuously brazed seams for ducts with largest dimension up to 72-inches
- b. Continuously welded or brazed seams for ducts with largest dimension greater than 72-inches

Sheet metal minimum thickness, transverse reinforcement between joints, and companion angle joints of ducts with longest side greater than 96 inches are in accordance with the following:

LONGEST SIDE (inches)	SHEET METAL GAGE ALL SIDES	COMPANION ANGLE (inches)	REINFORCEMENT ANGLES 24 INCHES ON CENTER MAXIMUM (BACK TO BACK)
97 to 108	16	2 by 2 by 1/8, two tie rods along angle	*Two 2 by 2 by 1/8, two tie rods along angle
109 to 132	16	2 by 2 by 3/16, two tie rods along angle	*Two 2 by 2 by 3/16, two tie rods along angle
133 and longer	14	2-1/2 by 2-1/2 by 3/16, with tie rods every 24 inches	*Two 2-1/2 by 2-1/2 by 3/16, with tie rods every 24 inches

3.3.3 Round Sheet Metal Ducts

3.3.3.1 Duct Gages and Reinforcement

Sheet metal minimum thickness, joints, and reinforcement between joints shall be in accordance with ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

Provide ducts with supplemental girth angle supports, riveted with brazed to duct. Locate girth angles as follows:

<u>DIAMETER, INCHES</u>	<u>REINFORCEMENT-MAXIMUM SPACING INCHES</u>
25 to 36	1-1/4 by 1-1/4, 1/8 thick, 72 inches on center
37 to 50	1-1/4 by 1-1/4, 1/8 thick, 60 inches on center
51 to 60	1-1/2 by 1-1/2, 1/8 thick, 48 inches on center

Use hex-shaped bolt heads and nuts, 5/16-inch diameter for ducts up to 50-inch diameter, and 3/8-inch diameter for 51-inch diameter ducts and larger.

Braze flanges to duct on outside of duct and intermittently welded with 1-inch welds every 4-inches on inside joint face. Remove excess filler

metal from inside face. Protect galvanized areas that have been damaged by welding with manufacturer's standard corrosion-resistant coating.

3.3.3.2 Duct Joints

Provide duct joints manufactured by machine, with spiral locksets up to and including 60-inch diameters, and to dimensional tolerances compatible with fittings provided. Draw-band girth joints are not acceptable.

Prepare slip joints by coating the male fitting with elastomer sealing materials, exercising care to prevent mastic from entering fitting bore. Leave only a thin annular mastic line exposed internally. Use sheet metal screws to make assembly rigid, not less than four screws per joint, maximum spacing 6-inches. Do not use pop rivets. Tape and heat seal all joints.

3.3.3.3 Duct Transitions

Where the shape of a duct changes, ensure the angle of the side of the transition piece does not exceed 15 degrees from the straight run of duct connected thereto.

Where equipment is installed in ductwork, ensure the angle of the side of the transition piece from the straight run of duct connected thereto does not exceed 15 degrees on the upstream side of the equipment and 22-1/2 degrees on the downstream side of the equipment.

3.3.4 Round, High Pressure, Sheet Metal Duct Installation

3.3.4.1 Joints

Provide an inner coupling to align the inner lining to maintain good airflow conditions equivalent to standard round high-pressure duct joints. Butt joints are not suitable for the inner liner. Accomplish this alignment by extending the liner of the fitting for slip joint into the pipe. For ducts over 34-inches inside diameter, provide a separate coupling for inner alignment, with the pressure shells joined by angle-ring flanged connections.

3.3.4.2 Insulation Ends

At the end of an uninsulated section or run where internally insulated duct connects to uninsulated spiral duct, fitting, fire damper or flexible duct, install an insulated end-fitting to bring the outer pressure shell down to nominal size.

3.3.5 Transverse Reinforcement Joints

Provide transverse reinforcements that are spot welded 4 inches on center. Weld transverse reinforcement at all corners to form continuous frames.

3.3.6 Joint Gaskets

For flanged joints, use neoprene full-face gaskets 1/8-inch thick, with Shore A 40 durometer hardness. Use one-piece gaskets, vulcanized at joints.

3.3.7 Radius Elbows

Fabricate elbow proportions and radius elbows in accordance with ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

3.3.8 Plenum Connections

Ensure round duct connections are welded joint bellmouth type.

Ensure rectangular duct connections are bellmouth type, constructed in accordance with ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966.

3.3.9 Access Openings

Install access panels in ductwork adjacent to fire dampers.

Minimum size of access opening is 12 by 18 inches, unless precluded by duct dimension.

Frame access openings with welded and ground miter joints, 1/8-inch thick strap steel, with 1/4 -inch studs welded to frame. Ensure cover plates are not less than 16-gage, reinforced as necessary for larger sizes.

In lieu of access doors, use readily accessible flanged duct sections upon approval. Provide stable hanger supports for disconnected duct terminal.

3.3.10 Duct Supports

Install duct support in accordance with ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966. Meet the minimum size for duct hangers as specified in ASHRAE EQUIP IP HDBK, Chapter 16, ASHRAE FUN IP, Chapter 32 and SMACNA 1966. Provide two hangers where necessary to eliminate sway. Support attachment to duct surfaces by bolt 4-inches on center.

Take the following into account in selection of a hanging system:

- a. Location and precedence of work under other sections
- b. Interferences of various piping and electrical conduit
- c. Equipment, and building configuration
- d. Structural and safety factor requirements
- e. Vibration, and imposed loads under normal and abnormal service conditions

Support sizes, configurations, and spacing are given to show the minimal type of supporting components required. If installed loads are excessive for the specified hanger spacing, hangers, and accessories reduce hanger spacing. After system startup, replace any duct support device which due to length, configuration, or size, vibrates or causes possible failure of a member. Do not use a ductwork support system that allows a cascade-type failure to occur.

Do not hang ductwork and equipment from roof deck, piping, or other ducts or equipment. Maximum span between any two points is 10-feet, with lesser

spans as required by duct assemblies, interferences, and permitted loads imposed.

Where support from metal deck systems is involved, coordinate support requirements with installation of metal deck.

3.3.10.1 Double-wall Ducts

Provide round, double-wall duct supports as recommended by the manufacturer except that minimum hanger ring and strap size is 1-1/2 inches by 1/8 inch.

3.3.10.2 Hangars

Attach hanger rods, angles, and straps to beam clamps. Receive approval from the Contracting Officer for concrete inserts, masonry anchors, and fasteners for the application.

Hardened high-carbon spring-steel fasteners fitted onto beams and miscellaneous structural steel are acceptable upon prior approval of each proposed application and upon field demonstration of conformance to specification requirements. Make fasteners from steel conforming to AISI Type 1055, treated and finished in conformance with SAE AMS 2480, Type Z (zinc phosphate base), Class 2 (supplementary treatment). Verify a 72-hour load-carrying capacity by a certified independent laboratory.

Where ductwork system contains heavy equipment, excluding air-diffusion devices and single-leaf dampers, hang such equipment independently of the ductwork by means of rods or angles of sizes adequate to support the load.

Cross-brace hangers to preclude swaying both vertically and laterally.

3.3.10.3 Installation

Ensure hanger spacing gives a 20-to-1 safety factor for supported load.

Maximum load supported by any two fasteners is 100 pounds.

Install hangers on both sides of all duct turns, branch fittings, and transitions.

Friction rod assemblies are not acceptable.

3.3.10.4 Strap-type Hangars

Support rectangular ducts up to 36-inches by strap-type hangers attached at not less than three places to not less than two duct surfaces in different planes.

Perforated strap hangers are not acceptable.

3.3.10.5 Trapeze Hangars

Support rectangular ducting, 36-inches and larger, by trapeze hangers. Support ducts situated in unconditioned areas and required to have insulation with a vapor-sealed facing on trapeze hangers. Space hangers far enough out from the side of the duct to permit the duct insulation to be placed on the duct inside the trapeze. Do not penetrate the vapor-sealed facing with duct hangers.

Where trapeze hangers are used, support the bottom of the duct on angles sized as follows:

<u>WIDTH OF DUCT,</u> <u>INCHES</u>	<u>MINIMUM BOTTOM ANGLE SIZE,</u> <u>INCHES</u>
30 and smaller	1-1/4 by 1-1/4 by 1/8
31 to 48	1-1/2 by 1-1/2 by 1/8
49 to 72	1-1/2 by 1-1/2 by 3/16
73 to 96	2 by 2 by 1/4
97 and wider	3 by 3 by 1/4

3.3.10.6 Purlins

Do not support ducting from roof purlins at points greater than one-sixth of the purlin span from the roof truss. Do not exceed 400 pounds load per hanger.

If the hanger load must exceed the above limit, provide reinforcing of purlin(s) or additional support beam(s). When an additional beam is used, have the beam bear on the top chord of the roof trusses, and also bear over the gusset plates of top chord. Stabilize the beam by connection to roof purlin along bottom flange.

Purlins used for supporting fire-protection sprinkler mains, electrical lighting fixtures, electrical power ducts, or cable trays are considered fully loaded. Provide supplemental reinforcing or auxiliary support steel for these purlins when used to support ductwork.

3.3.10.7 Vibration Isolation

3.3.11 Flexible Connectors for Steel Metal

Connect air-handling equipment, ducts crossing building expansion joints, and fan inlets and outlets to upstream and downstream components with treated woven-cloth connectors.

Install connectors only after system fans are operative and all vibration isolation mountings have been adjusted. When system fans are operating, ensure connectors are free of wrinkles caused by misalignment or fan reaction. Width of surface is curvilinear.

3.3.12 Insulation Protection Angles

Provide galvanized 20-gage sheet, formed into an angle with a 2-inch exposed long leg with a 3/8-inch stiffening break at outer edge, and with a variable concealed leg, depending upon insulation thickness.

Install angles over all insulation edges terminating by butting against a wall, floor foundation, frame, and similar construction. Fasten angles in place with blind rivets through the protection angle, insulation, and sheet metal duct or plenum. Install angles after final insulation covering has been applied.

3.3.13 Duct Probe Access

Provide holes with neat patches, threaded plugs, or threaded or twist-on caps for air-balancing pitot tube access. Provide extended-neck fittings where probe access area is insulated.

3.3.14 Openings In Roofs and Walls

Existing building openings are fixed in size and cannot be resized without authorization. Provide equipment to suit existing opening size.

3.4 FIELD QUALITY CONTROL

3.4.1 Ductwork Leakage Tests

Conduct complete leakage test of new ductwork in accordance with Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC. Perform tests prior to installing ductwork insulation.

3.4.2 Inspection

Inspect ductwork in accordance with SMACNA 1987.

3.5 CLOSEOUT ACTIVITIES

3.5.1 Operation and Maintenance

Submit 6 copies of the operation and maintenance manuals 30 calendar days prior to testing the medium and high pressure ductwork systems. Update data and resubmit for final approval no later than 30 calendar days prior to contract completion.

Ensure operation and maintenance manuals are consistent with manufacturer's standard brochures, schematics, printed instructions, general operating procedures and safety precautions.

3.5.2 Record Drawings

Provide record drawings with current factual information. Include deviations from, and amendments to, the drawings. Include concealed or visible changes in the work. Label drawings "As-Built".

-- End of Section --

SECTION 23 34 23.00 40

HVAC POWER VENTILATORS

02/17

PART 1 GENERAL

Provide a power roof ventilators complete with all components and accessory equipment as specified in this section.

Section 23 30 00 HVAC AIR DISTRIBUTION applies to work specified in this section.

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE 7-16 (2017; Errata 2018; Supp 1 2018) Minimum Design Loads and Associated Criteria for Buildings and Other Structures

ASTM INTERNATIONAL (ASTM)

ASTM A653/A653M (2023) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

ASTM B37 (2018) Standard Specification for Aluminum for Use in Iron and Steel Manufacture

ASTM B209 (2014) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

RCBEA GUIDE (2004) NASA Reliability Centered Building and Equipment Acceptance Guide

UNDERWRITERS LABORATORIES (UL)

UL 705 (2017; Reprint Aug 2022) UL Standard for Safety Power Ventilators

1.2 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Shop Drawings; G

Installation Drawings; G

SD-03 Product Data

Housing; G

Fan; G

Motor; G

Bases; G

Roof Curbs; G

Dampers; G

Screens; G

Sound Baffles; G

SD-06 Test Reports

SD-11 Closeout Submittals

Record Drawings; G

1.3 QUALITY CONTROL

Rate and label ventilators in accordance with the applicable standards of the Air Movement Control Association (AMCA), and indicate if the license bears the AMCA seal for both air and sound.

1.3.1 Predictive Testing and Inspection Technology Requirements

This section contains systems or equipment components regulated by NASA's Reliability Centered Building and Equipment Acceptance Program (RCBEA). This program requires the use of Predictive Testing and Inspection (PT&I) technologies in conformance with the RCBEA GUIDE to ensure that building equipment and systems have been installed properly and contain no identifiable defects that shorten the design life of a system or its components. Satisfactory completion of all acceptance requirements is required to obtain Government approval and acceptance of the Contractor's work.

Perform PT&I tests and provide submittals.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

2.1.1 Design Requirements

Submit the manufacturer's catalog data, including equipment and performance data, for power roof ventilator(s). As a minimum, include the following data:

- a. Fan Type
- b. Fan Specifications, including:
 - (1) Number of rotating fan blades/vanes
 - (2) Number of stationary fan blades/vanes
 - (3) Rotating speed(s)
 - (4) Number of belts (if belt-driven)
 - (5) Belt lengths- measured at the pitch line (if belt-driven)
 - (6) Diameter of the drive sheave at the drive pitch line (if belt-driven)
 - (7) Diameter of the driven sheave at the drive pitch line (if belt-driven)
- c. Location of Installation
- d. Identification Number
- e. Date of Installation (Required or Actual Acceptance Date)
- f. Applicable reference drawing number(s)

Submit detailed shop drawings for power roof ventilator systems.

Provide roof ventilators that comply with UL 705 and are furnished complete with bases, curbs, flashing flanges, noise baffles, dampers, damper controls, louvers, and screens, as indicated.

Provide ventilators that are designed for windloads in accordance with ASCE 7-16 with the installed design not less than 130 miles per hour windload. Ensure that the structural bracing is properly spaced to accommodate this loading and meets the design requirements of the covering material. Ensure that ventilators are adequately reinforced and well-braced with the joints properly formed. Ensure that the edges are wired or beaded where necessary to ensure rigidity. Prevent galvanic action between different metals in direct contact by providing nonconductive separators. Make all soldering even and smooth.

Provide corrosion-resistant steel bolts, rivets, and other fastenings used in connection with protected metal.

2.2 COMPONENTS

2.2.1 Housing Style

Provide round-mushroom style power roof ventilator as indicated.

2.2.2 Fan Type

Provide fans of the following types:

2.2.2.1 Type C-PRV Centrifugal, Direct Drive

For Type C-PRV ventilators, provide a centrifugal roof ventilator with direct drive, nonoverloading, backward-inclined wheel. Provide a vibration-isolated drive with an elastomer. Provide drive components that are mounted in a compartment isolated from the airstream.

2.2.2.2 Type CB-PRV Centrifugal, V-Belt Drive

For Type CB-PRV ventilators provide a centrifugal roof ventilator with V-belt drive, nonoverloading, backward-inclined wheel. Provide a vibration-isolated drive with an elastomer. Provide drive components that are mounted in a compartment isolated from the airstream.

2.2.2.3 Type P-PRV Propeller, Direct Drive

For Type P-PRV ventilators, provide a propeller roof ventilator with direct drive that is vibration-isolated with an elastomer. Provide drive components that are mounted in a compartment isolated from the airstream.

2.2.2.4 Type PB-PRV Propeller, V-Belt Drive

For Type PB-PRV ventilators, provide a propeller roof ventilator with V-belt drive that is vibration-isolated with an elastomer. Provide drive components that are mounted in a compartment isolated from the airstream.

2.2.2.5 Type VA-PRV Vane Axial, Direct Drive

For Type VA-PRV ventilators, provide a vane axial roof ventilator with direct drive that is vibration-isolated with an elastomer.

2.2.2.6 Type VAB-PRV Vane Axial, V-Belt Drive

For Type VAB-PRV ventilators, provide a vane axial roof ventilator with V-belt drive that is vibration-isolated with an elastomer.

2.2.2.7 Type TA-PRV Tube Axial, Direct Drive

For Type TA-PRV ventilators, provide a tube axial roof ventilator with direct drive that is vibration-isolated with an elastomer.

2.2.2.8 Type TAV-PRV Tube Axial, V-Belt Drive

For Type TAV-PRV ventilators, provide a tube axial roof ventilator with V-belt drive that is vibration-isolated with an elastomer.

2.2.3 Fan Motor

Provide single-phase, 120 V, 60 Hz, split-phase, belt-driven motors less than 1/2 horsepower, with permanently lubricated ball bearings.

Provide three-phase , 460 V, 60 Hz motors 1/2 horsepower and larger.

Provide motors with local disconnects to allow for fan and motor maintenance. Provide all motors with thermal-overload protection. For motors located in airstreams, use a totally enclosed type.

Use energy efficient permanent split capacitor motors, single phase, 60 Hz direct-drive motors 1/2 horsepower or less.

2.2.4 Bases

When bases are provided with the ventilators, use factory-formed bases of the type indicated, constructed of the same material as the hoods, and of the thickness necessary to meet the design requirement for connection to the roof. Provide bases that are suitable for raised-curb mounting where indicated. Form curb flanges of the base as cap flashing, extending at least 2 inches over the roofing base. Where indicated or required, extend the shafts of ventilators a sufficient distance through the supporting construction to permit attachment of vent ducts.

2.2.5 Roof Curbs

Provide factory-formed metal ventilator curbs of the type and design required for the ventilator and suitable for the roof configuration and flashing.

Provide job-built curbs that conform to the recommendations of the ventilator manufacturer, that are sized correctly for the ventilator, and that are suitable for the type of supporting roof construction.

2.2.6 Back-Draft Dampers

Provide gravity-operated back-draft dampers with adjustable counterweights constructed of the same material as fan housing.

Provide motor-operated back-draft dampers constructed of the same material as fan housing.

Interlock damper-actuating motor with the fan motor.

2.2.7 Screens

Provide bird screens with frames constructed of the same material as that used in the ventilators and ensure the screens are securely attached in a manner that permits easy removal for access and cleaning.

2.2.8 Sound Baffles

Provide permanently constructed sound baffles that are impervious to moisture. Provide removable baffles.

2.3 MATERIALS

Provide manufacturers' standard materials.

2.3.1 Aluminum Alloy

Provide aluminum alloy in accordance with ASTM B209 and ASTM B37.

2.3.2 Zinc-Coated Steel

Provide zinc-coated steel in accordance with ASTM A653/A653M.

2.3.3 Fibrous Glass

Provide fibrous glass ventilators that are molded from a glass-fiber-reinforced polyester resin with a pigmented polyester resin

gel coat in the manufacturer's standard color, and that are between 0.02 inches and 0.06 inches thick. Provide a matrix material that is not less than 30 percent, by weight, of chopped-fiber and random-strand glass fibers, and that is thoroughly saturated and impregnated with not more than 70 percent high-solids polyester resin with not less than 5 percent antimony trioxide fire-retardant additive. Provide material that is smooth and uniform in texture, and color throughout the cross section and that is shatter-resistant. Ensure that the material is free from visual defects, foreign inclusions, cracks, crazing, die lines, pinholes, and striations. Ensure that the material has no areas that are unsaturated or lacking resin, and no areas with excessive resin.

PART 3 EXECUTION

3.1 INSTALLATION

Submit installation drawings for power roof ventilators.

Install power roof ventilators in accordance with the manufacturer's installation instructions. Coordinate installation of ventilators with other work. Coordinate anchors, attachments, and other items to be built for installation as the work progresses. Rigidly install ventilators in a weathertight and watertight manner that is free from vibration.

3.1.1 Lubrication

Ensure the movable parts of dampers and related operating hardware are lubricated in accordance with manufacturer's printed instructions and that they operate smoothly and quietly without binding.

3.2 FIELD QUALITY CONTROL

3.2.1 Tests

Perform PT&I tests and provide submittals.

After installation, test each power roof ventilator to demonstrate proper operation at indicated and specified performance requirements, including the running, balance, noise, and proper direction of fan rotation.

3.2.2 Acceptance

Prior to final acceptance, use precision alignment devices to demonstrate that the fan and motor are aligned as specified by the manufacturer.

Prior to final acceptance, verify conformance to specifications with vibration analysis. Ensure vibration levels are not more than .075 in/sec at 1 times the run speed and at the fan/blade frequency, and not more than 0.04 in/sec at other multiples of the run speed.

3.3 CLOSEOUT ACTIVITIES

Submit detailed record drawings upon completion of the installation.

-- End of Section --

SECTION 23 35 19.00 20

INDUSTRIAL VENTILATION AND EXHAUST
02/10, CHG 2: 08/18

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC. (AMCA)

AMCA 99	(2016) Standards Handbook
AMCA 99-0401	(1986) Classifications for Spark Resistant Construction
AMCA 201	(2002; R 2011) Fans and Systems
AMCA 210	(2016) Laboratory Methods of Testing Fans for Aerodynamic Performance Rating
AMCA 211	(2013; Rev 2017) Certified Ratings Program Product Rating Manual for Fan Air Performance
AMCA 300	(2014) Reverberant Room Method for Sound Testing of Fans
AMCA 301	(2014) Methods for Calculating Fan Sound Ratings from Laboratory Test Data
AMCA 500-D	(2018) Laboratory Methods of Testing Dampers for Rating
AMCA CRP	(Online) Directory of Products Licensed Under the AMCA International Certified Ratings Program

AIR-CONDITIONING, HEATING AND REFRIGERATION INSTITUTE (AHRI)

AHRI 1060 I-P	(2014) Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Heat Equipment
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AMERICAN BEARING MANUFACTURERS ASSOCIATION (ABMA)

ABMA 9	(2015) Load Ratings and Fatigue Life for Ball Bearings
ABMA 11	(2014) Load Ratings and Fatigue Life for Roller Bearings

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

ACGIH-2092S (2004) Industrial Ventilation: A Manual
of Recommended Practice

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 360 (2016) Specification for Structural Steel
Buildings

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M (2020; Errata 1 2021) Structural Welding
Code - Steel

AWS D1.3/D1.3M (2018) Structural Welding Code - Sheet
Steel

AWS Z49.1 (2021) Safety in Welding and Cutting and
Allied Processes

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M (2019) Standard Specification for Carbon
Structural Steel

ASTM A123/A123M (2017) Standard Specification for Zinc
(Hot-Dip Galvanized) Coatings on Iron and
Steel Products

ASTM A167 (2011) Standard Specification for
Stainless and Heat-Resisting
Chromium-Nickel Steel Plate, Sheet, and
Strip

ASTM A653/A653M (2023) Standard Specification for Steel
Sheet, Zinc-Coated (Galvanized) or
Zinc-Iron Alloy-Coated (Galvannealed) by
the Hot-Dip Process

ASTM A1011/A1011M (2023) Standard Specification for Steel
Sheet and Strip, Hot-Rolled, Carbon,
Structural, High-Strength Low-Alloy,
High-Strength Low-Alloy with Improved
Formability, and Ultra-High Strength

ASTM B117 (2019) Standard Practice for Operating
Salt Spray (Fog) Apparatus

ASTM B152/B152M (2019) Standard Specification for Copper
Sheet, Strip, Plate, and Rolled Bar

ASTM C920 (2018) Standard Specification for
Elastomeric Joint Sealants

ASTM D1330 (2004; R 2010) Rubber Sheet Gaskets

ASTM D1654 (2008; R 2016; E 2017) Standard Test
Method for Evaluation of Painted or Coated

Specimens Subjected to Corrosive
Environments

ASTM D2000 (2018) Standard Classification System for
Rubber Products in Automotive Applications

CALIFORNIA DEPARTMENT OF PUBLIC HEALTH (CDPH)

CDPH SECTION 01350 (2017; Version 1.2) Standard Method for
the Testing and Evaluation of Volatile
Organic Chemical Emissions from Indoor
Sources using Environmental Chambers

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 1 (2022) Standard for Industrial Control and
Systems: General Requirements

NEMA ICS 2 (2000; R 2020) Industrial Control and
Systems Controllers, Contactors, and
Overload Relays Rated 600 V

NEMA ICS 6 (1993; R 2016) Industrial Control and
Systems: Enclosures

NEMA MG 1 (2021) Motors and Generators

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 65 (1993) Processing and Finishing of Aluminum

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National
Electrical Code

NFPA 91 (2020) Standard for Exhaust Systems for
Air Conveying of Vapors, Gases, Mists and
Noncombustible Particulate Solids

NFPA 664 (2020) Standard for the Prevention of
Fires and Explosions in Wood Processing
and Woodworking Facilities

RUBBER MANUFACTURERS ASSOCIATION (RMA)

RMA IP-20 (2007) Specifications for Drives Using
Classical V-Belts and Sheaves.
Specifications for A, B, C, and D Cross
Sections

RMA IP-22 (2007) Specifications for Drives Using
Narrow V-Belts and Sheaves (Joint
RMA/MPTA), 4th Edition

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION
(SMACNA)

SMACNA 1378 (1995) Thermoplastic Duct (PVC)
Construction Manual, 2nd Edition

SMACNA 1403 (2008) Accepted Industry Practice for Industrial Duct Construction, 2nd Edition

SMACNA 1520 (1999) Round Industrial Duct Construction Standards, 3rd Edition

SMACNA 1922 (2004) Rectangular Industrial Duct Construction Standards, 2nd Edition

SMACNA 1972 CD (2012) HVAC Air Duct Leakage Test Manual - 2nd Edition

SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC Paint 20 (2019) Zinc-Rich Primers (Type I, Inorganic, and Type II, Organic)

SSPC SP 5/NACE No. 1 (2007) White Metal Blast Cleaning

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT (SCAQMD)

SCAQMD Rule 1168 (2017) Adhesive and Sealant Applications

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-DTL-12276 (2006; Rev E; Notice 1 2011; Notice 2 2016; Notice 3 2021) Varnish, Phenolic, Baking

MIL-DTL-24441 (2009; Rev D; Notice 1 2021) Paint, Epoxy-Polyamide, General Specification for

MIL-P-21035 (1991; Rev B; Notice 2 2003; Notice 3 2021) Paint, High Zinc Dust Content, Galvanizing Repair (Metric)

MIL-PRF-23236 (2009; Rev D) Coating Systems for Ship Structures

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

CID A-A-272 (Rev B; Notice 1) Caulking Compounds

FS TT-S-001543 (Rev B; Notice 1) Sealing Compound: Silicone Rubber Base (For Calking, Sealing, and Glazing in Buildings and Other Structures)

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

29 CFR 1910.219 Mechanical Power Transmission Apparatus

UNDERWRITERS LABORATORIES (UL)

UL 33 (2010; Reprint Apr 2020) Heat Responsive Links for Fire-Protection Service

UL 181 (2013; Reprint Dec 2021) UL Standard for Safety Factory-Made Air Ducts and Air

Connectors

UL 214 (1997; Rev thru Aug 2001) Tests for
Flame-Propagation of Fabrics and Films

1.2 GENERAL REQUIREMENTS

1.2.1 SMACNA Duct Construction Manuals

The recommendations in the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) duct construction manuals must be considered mandatory requirements. Substitute the word "must" for "should" in these manuals.

1.2.2 Fan Data

For fans include fan curves or rating tables and derating factors. Provide certified performance curves showing total pressure, power, and mechanical efficiency versus flow rate of the operating density and fan speed. All areas of unstable operation must be indicated. For fans equipped with adjustable capacity controls such as variable inlet or vaneaxial fans with adjustable blade settings, minimum and maximum performance must be indicated along with performance for fire intermediate settings.

1.2.3 Natural Ventilation

Evaluate natural ventilation for appropriate spaces, and design air distribution systems to operate in the same direction as natural ventilation to reduce energy cost of pumping outdoor air.

1.2.4 Industrial Ventilation and Exhaust Systems

Submit drawings including fan installation drawings; duct systems; supports and anchor location and load imposed.

1.2.5 Start-Up Tests

Submit start-up tests reports in accordance with the paragraph TESTING, ADJUSTING, AND BALANCING. Submit final test report for systems tested, describing all test apparatus, instrumentation calculations, factors, flow coefficients, sound levels, and equipment data based on ACGIH-2092S recommended forms or reasonable facsimiles thereof to suit project conditions. Adjustment and setting data must be included in test report. Submit sound level test reports for high noise level equipment.

1.2.6 Related Requirements

Conform to Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND METHODS as well as additional requirements specified herein.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Industrial Ventilation and Exhaust Systems; G

SD-03 Product Data

Fans; G

Dampers; G

Flexible Connectors

Flexible Duct; G

Gaskets

Protective Coating Materials

Sealants

Access Ports; G

Damper Regulators; G

Blast Gates; G

Vibration Isolators; G

Ductwork, Dust Collection

Steel Ducts; G

Recycled Content of Ductwork Steel Components; S

Recycled Content of Protectively Coated Steel Ducts; S

Indoor Air Quality for Duct Sealants; S

SD-06 Test Reports

Fan Tests, including Sound Power Level Tests; G

Ventilation and Exhaust System Start-Up Tests; G

Sound Level Tests; G

SD-07 Certificates

Welding Procedures; G

Welding Test Agenda; G

Welding Test Procedures; G

Welders' Identification; G

Fiberglass Fan Servicer Experience Information; G

SD-10 Operation and Maintenance Data

Fans, Data Package 2; G

Industrial Ventilation and Exhaust Systems, Data Package 2; G

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

SD-11 Closeout Submittals

Posted Operating Instructions

Submit text of posted operating instructions for ventilation and exhaust systems.

1.4 QUALITY ASSURANCE

1.4.1 Welders' Identification

Submit a listing of the names and identification symbols to be used to identify the work performed by the welder or welding operator who after completing a welded joint must identify it as his work by applying his assigned symbol for a permanent record.

1.4.2 Fiberglass Fan Servicer Experience Information

Submit text.

1.4.3 Qualified Personnel

Operations involving joining thermoplastic ductwork by solvent or hot gas and joining fiberglass ductwork by laminating must be performed by personnel certified by the manufacturer as qualified for the work.

1.4.4 Qualification of Welders

Qualify each welder or welding operator by tests using equipment, welding procedures and a base metal and electrode or filler wire from the same compatible group number that will be encountered in the applicable welding test procedures. Welders or welding operators who make acceptable procedure qualification test welds will be considered performance qualified for the welding procedure used. Determine performance qualification in accordance with AWS D1.1/D1.1M. Notify the Contracting Officer 24 hours in advance as to the time and place of tests and wherever practical perform the tests at the work site.

1.4.5 TAB Requirements

Requirements are specified in Section 23 05 93 TESTING, ADJUSTING AND BALANCING and Section 23 08 01.00 20 TESTING INDUSTRIAL VENTILATION SYSTEMS.

1.5 POSTED OPERATING INSTRUCTIONS

Provide for ventilation and exhaust system. In addition, permanently mark, drill, and pin as an integral part of device, final adjustment and settings pursuant to testing, adjusting, and balancing.

1.6 SAFETY PRECAUTIONS

1.6.1 Guards and Screens

Provide metal personnel safety guards for normally accessible unducted fan inlets and discharges and moving power transmission components in accordance with OSHA 29 CFR 1910.219.

1.6.2 Welding

Conform to AWS Z49.1 for safety in welding and cutting.

PART 2 PRODUCTS

2.1 FANS, GENERAL REQUIREMENTS FOR

2.1.1 General Performance, Component, and Other Requirements

Fans must have certified performance ratings as evidenced by conformance to the requirements of AMCA 211, and must be listed in AMCA CRP, or must be currently eligible for such listing. Fans must generally be in accordance with AMCA 99 unless superseded by other requirements stated elsewhere herein. Determine performance data for fans in accordance with AMCA 210. Select fans to minimize the exposure of personnel working in or occupying the immediate installation area. The total sound power level of the fan tests must not exceed 90 dBA when tested per AMCA 300 and rated per AMCA 301, or it must be provided with an appropriate attenuation device or devices. Scheduled fan performance is the performance required under specified or indicated installation conditions with specified or indicated accessories. The net installed air performance of the fan, with accessories/appurtenances in place, must be sufficient to meet the scheduled performance within the limits of the fan rating certification tolerance. Affix the manufacturer's product identification nameplate to each unit. Apply additional requirements for specific service or generic type or class of fan. If nonuniform air flow conditions are likely to be encountered, contact the fan manufacturer to ensure that the fan is rated for the additional fan inlet and outlet effect. Install fans to minimize fan system effect in accordance with AMCA 201. Fans must be listed in the Directory of Products licensed to use AMCA seal.

2.1.2 Bearings and Lubrication

Precision anti-friction or sleeve type with provisions for self-alignment and for radial and thrust loads imposed by the service. Provide water-cooled bearings where required for the service or recommended by the manufacturer.

2.1.2.1 Anti-friction Bearings

Constructed of steel alloys with a certified L-10 minimum rated life of 20,000 hours under load conditions imposed by the service. Rated and selected in accordance with ABMA 9 and ABMA 11. Provide with dust-tight seals suitable for environment and lubricant pressures encountered; cast ferrous metal housing, bolted-split pillow block type where located within fan casings; grease lubricated with provisions to prevent overheating due to excess lubricant; surface ball check type grease supply fittings. Provide manual or automatic grease pressure relief fittings visible from normal maintenance locations. Include lubrication extension tubes where necessary to facilitate safe maintenance during operation and fill tubes

with lubricant prior to equipment operation. Prelubricated, sealed, anti-friction bearings, which conform to above specified materials and L-10 life requirements, may be provided for fans requiring less than 1/2 horsepower.

2.1.2.2 Sleeve Bearings

Premounted, self-aligning, continuous oil supply, single or double ring lubricated, insert type, with suitable provisions for shaft expansion and such thrust as may be imposed by service loads. Provide water cooling for shaft surface speed exceeding 1200 feet per minute. Provide each sleeve bearing with approximately 16 ounce capacity constant level oiler and oil level gage. Include on sleeve bearing submittal data: Bearing manufacturing source, type, lubricant, clearances, "L/D" ratio, antifriction metal, belt angle, shaft speed, shaft critical speed, Brinell hardness at journal, and shaft surface finish at journal in micro-inches.

2.1.3 Motors and Motor Starters

Conform to NEMA MG 1 and NEMA ICS 1 and NEMA ICS 2. Motors less than one hp must meet NEMA High Efficiency requirements. Motors one hp and larger must meet NEMA Premium Efficiency requirements. Motors must not exceed 1800 rpm, unless otherwise indicated, and must be variable-speed, dripproof enclosure type. Provide reduced voltage type motor starters with weather resistant NEMA 3R enclosure in accordance with NEMA ICS 6. Provide single-phase motors with inherent thermal overload protection with manual reset. Provide three-phase motors with thermal overload protection in the control panel. Provide permanently lubricated or grease-lubricated ball or roller bearings; auxiliary lubrication and relief fittings on outside of fan casing; arrange grease lines to minimize pressure on bearing seals. Motor power must not be less than brake power required with blades set at maximum pitch angle at any air delivery from the indicated amount down to 50 percent thereof.

2.1.4 Guards and Screens

Construct guards and screens to provide, as applicable: required strength and clearance with minimal reduction in free area at fan inlets and discharges; cooling; access panels for tachometer readings; ease of sectional disassembly for maintenance and inspection functions where guard total weight exceeds 50 pounds; weather protection where components are weather exposed. Installed guards and screens must not negate noise control and vibration isolation provisions. For burn protection, insulate surfaces when service temperatures exceed 140 degrees F as part of work under Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.1.5 Power Transmission Components

2.1.5.1 Fan Drives

Direct type as indicated. V-belt drives must conform to RMA IP-20 and RMA IP-22. Drives must be applied in accordance with the manufacturer's published recommendations, unless specified otherwise. Base power rating of a V-belt drive on maximum pitch diameter of sheaves. Provide classical belt section adjustable sheave type, with a minimum service factor of 1.5 for drives with motors rated up to and including 30 hp. Provide classical section or narrow section, fixed sheave or adjustable sheave type with a minimum 1.5 service factor for drives with motors rated over 30 hp.

2.1.5.2 Sheaves

Statically and dynamically balanced, machined cast ferrous metal or machined carbon steel, bushing type, secured by key and keyway. Pitch diameter or fixed sheaves and adjustable sheaves, when adjusted to specified limits, must not be less than that recommended by NEMA MG 1. Select adjustable sheaves that provide the required operating speed with the sheave set at midpoint of its adjustment range. The adjustment range for various size and type belts must be: 16 percent, minimum for Classical section belts; 12 percent, minimum for Narrow section belts. Provide companion sheaves for adjustable sheave drives with wide groove spacing to match driving sheaves, except that standard fixed pitch spacing may be used for all two-through-four groove drives whose center-to-center dimensions exceed the following: "A" and "B" Section 16 inches; "C" Section 25 inches; "D" Section 36 inches. Furnish endless, static dissipating, oil-resistant, synthetic cloth or filament reinforced elastomer construction belts.

2.1.6 Special Construction for Hazardous Areas

2.1.6.1 Spark-Resistant

Construct units in accordance with AMCA 99-0401; Type A . Provide Type B construction and electrical grounding of fan parts and grounding to building structure where fume or vapor handling systems conforming to NFPA 91 are specified. Do not place bearings in the air stream.

2.1.6.2 Explosion Proof

Construct fans to AMCA 99-0401, Type A spark-resistant requirements where explosion-proof electrical components are specified or indicated to conform to NFPA 70, Class , Group , Division requirements.

2.1.7 Protective Coating for Fans

Prepare and coat fans as follows: Replace bolts required to provide access or adjustment and normally threaded into the coated surface with studs or bolts having heads continuously welded inside. Omit sharp edges, self-tapping screws, and permanent threads protruding into the coated surface. Eliminate hairline cracks and sharp inside corners by continuous welding, brazing, or filling with high melting point solder. Seal impeller hub to the shaft. Construct housing split to use external throughbolts. Flange inlet and outlet and consider as fan interior. Peen or grind welds smooth, and grind outside corners to approximately 1/16 inch radius. Sandblast metal surfaces to white metal in accordance with SSPC SP 5/NACE No. 1. Coat interior surfaces of housing in contact with airstream, including inlet, impeller and shaft, flange faces, shaft seal, exterior surfaces of housing . Do not coat bearings, coupling, motor, drive, or other auxiliaries. Statically and dynamically balance the fan in two planes after coating and finishing, and where material has been removed, refinish and rebalance the fan as specified herein.

2.2 CENTRIFUGAL FANS

2.2.1 General Requirements for Centrifugal Fans

Provide fan of backward inclined type blades with automatic inlet vanes . Arrange fans for indicated service, and construct for the applicable AMCA 99Class pressure ratings as indicated for system design pressure and

temperature. Fan shaft must be solid steel, ground and finished as required for the service, with first critical speed a minimum 25 percent higher than cataloged fan speed. Select fan for maximum efficiency, minimum noise, and stability during all modes of system operation. Vibration isolation mountings must be spring type and limit vibration transmissibility to a maximum 5 percent of the unbalanced force at lowest equipment speed, unless otherwise specified or indicated. Arrangement and drives must be as indicated.

2.2.2 In-line Centrifugal Fans

Welded steel casings, centrifugal backward inclined blades, stationary discharge conversion vanes, internal and external belt guards and adjustable motor mounts. Inlet and outlet connections for fan casings to duct work and equipment casings, may be of the slip fit or flanged type. Provide guards for discharges. Rate fans with guards in place. Air must enter and leave the fan axially. Inlet must be streamlined and conversion vanes must eliminate turbulence and provide smooth discharge air flow. Enclose fan bearings and drive shafts, and isolate from the air stream. Fan bearings must be mechanically sealed against dust and dirt and must be self-aligning, pillow block ball or roller type. Motor and drive must be provided by fan manufacturer.

2.3 TUBEAXIAL FANS

Direct-connected with adjustable blade impeller or V-belt driven. When direct connected, fans must be driven by totally-enclosed, air-over (TEAO), flanged or end mounted motors. When belt-driven, provide internal and external belt guards and adjustable motor mounts.

2.3.1 Fan Impeller Blades

Air-foil type , designed to provide the efficiency and sound level indicated. In fan selection, consider and account for any losses due to the size of the motor in relation to the fan hub diameter. Impeller blades of direct-driven fans must be adjustable to permit varying performance over a range of volume and pressure. Index the hub to facilitate setting the angle of the blades uniformly and accurately from minimum to maximum angle; provide stops to avoid overloading motor. Furnish motor with the factory blade maximum setting included in the fan nameplate data.

2.3.2 Fan Casings

Cylindrical, or welded steel construction, with flanged inlets and outlets. Assemble motor support and guide vanes by welding. Provide casings with bolted or hinged access plates adequate for inspection and servicing of internal parts.

2.4 BATHROOM AND KITCHEN FANS

Power used must be a maximum of 13 watts for 50 cfm fans; 15 watts for 70 cfm fans; 17 watts for 90 cfm fans; and 20 watts for 100 cfm fans. Noise levels must not exceed 0.5 sones for 50 to 70 cfm fans; 1.0 sones for 90 cfm fans; and 1.5 sones for 100 cfm fans. Fan lights must be compact fluorescent.

2.5 BASIC MATERIALS

2.5.1 Coated and Uncoated Carbon Steel Sheets, Plates, and Shapes

2.5.1.1 Mill Galvanized Steel Sheet

ASTM A653/A653M, lock forming quality, Coating G-90, 400 degrees F, maximum.

2.5.1.2 Mill Galvanized Steel Shapes

ASTM A36/A36M galvanized in accordance with ASTM A123/A123M .

2.5.1.3 Uncoated (Black) Carbon Steel Sheet

ASTM A1011/A1011M.

2.5.1.4 Uncoated (Black) Carbon Steel Plates and Shapes

ASTM A36/A36M.

2.5.2 Corrosion Resistant (Stainless) Steel

ASTM A167, Type 304L or Type 316L with mill finish, except as otherwise specified.

2.5.3 Corrosion Protection

Treat equipment fabricated from ferrous metals that do not have a zinc coating conforming to ASTM A123/A123M for prevention of corrosion with a factory coating or paint system that will withstand 125 hours in a salt-spray fog test except that equipment located outdoors must withstand 500 hours. Perform salt-spray fog test in accordance with ASTM B117. Each specimen must have a standard scribe mark as defined in ASTM D1654. Upon completion of exposure, evaluate and rate the coating or paint system in accordance with procedures A and B of ASTM D1654. The rating of failure at the scribe mark must be not less than six (average creepage not greater than 1/8 inch). The rating of the unscribed area must be less than ten (no failure). Thickness of coating or paint system on the actual equipment must be identical to that on the test specimens with respect to materials, conditions of application, and dry-film thickness.

2.6 HEAT RECOVERY SYSTEMS

Heat recovery systems must be utilized in ventilation units (100 percent outside air units) where the temperature differentials between supply air and exhaust air is significant. Heat recovery systems must operate at a minimum of 70 percent efficiency. The heat recovery systems must have factory-installed microprocessor controller that in turn can be connected to a Direct Digital Control (DDC) Building Automation System to monitor temperatures, wheel operation, filter cleanliness, defrost control, and other critical conditions. Prefilters must be provided in all heat recovery systems before the heat recovery equipment.

2.6.1 Unit Casing

Provide a self supporting unit casing constructed of minimum 0.04 inches thick extruded aluminum profiles and aluminum zinc sheet steel that create a double wall. The base of the casing must be constructed as a continuous condensate drain with a total of four connection possibilities. The

casing bottom, top, and sides must be insulated with 2 inch thick fibrous glass insulation with a minimum density of 6 lb per cubic foot or another material with equivalent insulating value. Provide a partition to isolate the exhaust and supply airstreams from each other to avoid cross contamination. Partition must be a minimum of 0.075 inches galvanized steel. Provide stainless steel casing for corrosive air streams. The casing must be designed for diagonal mounting of the heat exchanger access from the side for maintenance and cleaning. The casing must be designed with an integral defrost control damper on the heat exchanger section for defrost control. Provide full size access doors for checking the heat exchanger section.

2.6.2 Heat Exchanger Section

2.6.2.1 Enthalpy Wheel

A desiccant-impregnated enthalpy wheel with variable speed rotary wheel must be used in the supply and exhaust systems. Wheels must contain media made of a lightweight polymer that is coated with a corrosion-resistant finish. Etched or oxidized surfaces are not acceptable. Heat transfer surfaces must be coated with a non-migrating (permanently bonded) absorbent. Desiccant must be silica gel for maximum latent energy transfer. Wheel must allow laminar flow but not radial, and prevent leakage, bypassing, and cross contamination by cross flow within wheel. The wheel must have rotor seals specifically designed to limit cross-contamination, and a rotation detector. Should rotation stop, the rotation detector must alarm the HVAC control system. Wheel must not condense water directly or require a condensate drain for summer or winter operation. Performance rating must be in accordance with AHRI 1060 I-P.

2.6.3 Defrost Control Damper Section

Provide an integral defrost control damper section with electric damper motor for defrost control of the heat exchanger section. The defrost control dampers must be mounted upstream of the heat exchanger section and must be capable of preventing frost build-up on the plates of the heat exchanger. Drain pan must be stainless steel. The damper motor must be located outside of both airstreams.

2.6.4 Angle Filter Box

Provide a side access, galvanized steel duct mounted filter box assembly with integral holding frames suitable for accommodating 2 inch thick filters with a minimum efficiency reporting value of 13. Provide filter box constructed of minimum 0.05 inch thick galvanized steel with extruded aluminum tracks and individual universal holding frames with polyurethane foam gaskets and positive sealing clips designed to accommodate various standard size filters in various efficiency ranges. Provide access doors with positive sealing, heavy duty quick opening half-twist latches and sponge neoprene gasketing on each side of filter box for removal and replacement of filters. For each filter box provide one magnehelic gauge or inclined manometer with static pressure taps, shut-off and vent cocks, and aluminum tubing with range 0.0073 to 0.21 psi.

2.7 FIRE DAMPERS

Provide guillotine constructed and rated in accordance with AMCA 500-D. Furnish dampers for indicated stream flow, to equal or exceed fire resistance rating of 1 1/2 hours. Fire damper must be rattle-free and

must cause a minimum 5 percent increase in stream velocity or system static pressure. Provide building penetration collars in accordance with AMCA 500-D and NFPA 91, unless otherwise indicated. Provide one spare fusible link for testing of each fire damper operation and one spare fusible link for each 10 fire dampers, but not less than two.

2.8 MISCELLANEOUS MATERIALS

2.8.1 Filler Metal, Welding

AWS filler metal specification and grade compatible with base materials to develop full joint strength.

2.8.2 Flashing Materials

Mill galvanized, phosphatized, steel sheet with minimum spangle, conforming to ASTM A653/A653M, Coating G90, 24 gage minimum thickness. Mill No. 1 or 2D finished, stainless steel, fully annealed, soft temper, conforming to ASTM A167, Type 304, 0.015 inch minimum thickness. Mill finished copper, conforming to ASTM B152/B152M, minimum 16 ounces per square foot.

2.8.3 Flexible Connectors

2.8.3.1 General Service

Airtight, fire-retardant, fume and vapor resistant, chloroprene or chlorosulfonated polyethylene impregnated, woven fibrous glass fabric, rated for continuous service at 250 degrees F, conforming to UL 214, with 20 ounce per square yard weight for service at 2 inches water gage and under and 30 ounce per square yard weight for service over 2 inches water gage. Provide with or without integral 24 gage mill galvanized sheet metal connectors.

2.8.3.2 Acoustic Service

Provide as second layer for nonpressure service to 140 degrees F, leaded sheet vinyl, a minimum 0.055 inches thick, weighing a minimum 0.87 pounds per square foot, capable of 10 dBA attenuation in 10 to 10,000 Hz range, suitable for solvent seam or overlap joining and banding.

2.8.3.3 Service

1/8 inch thick, single-ply, synthetic fabric reinforced chloroprene suitable for 225 degrees F.

2.8.3.4 High Temperature Service

- a. Bellows type metal expansion joints, temperature range minus 20 degrees F to 800 degrees F, plus or minus 100 inches water gage .
- b. Fabric reinforced, insulated, elastomeric cover expansion joint for operating temperature up to 400 degrees F type for 40 inches water gage positive or negative pressure , with interior liner or baffle.

2.8.4 Flexible Duct

2.8.4.1 Metallic Type

Single-ply zinc-coated carbon steel , self-supporting to 8 foot spans with corrugated and interlocked, folded and knurled type seam construction, bendable without damage through 180 degrees with a throat radius approximately 10 times the duct diameter, airtight, rated for positive or negative working pressure of 15 inches water gage at 650 degrees F for galvanized steel and stainless steel UL 181, Class 1 rated, conforming to NFPA 91.

2.8.4.2 Wire Reinforced Fabric Type

Elastomer impregnated woven synthetic fabric, bonded to and supported by corrosion protected or corrosion resistant spring steel helix, rated for positive or negative working pressure of 15 inches water gage at 250 degrees F UL 181, Class 1 labeled. Provide with manufacturer's standard metallic connection collar and clamping fastener assembly fitted with dampers .

2.8.4.3 Ball Joints

Fabricated from cast iron or formed sheet metal with outer sections secured with bolts. Provide each half of the ball joint with tubular stubs for connecting ducts.

2.8.4.4 Slip Joints

Fabricated from tubular sheet metal sections. Provide outer tube with formed steel flat bar clamps. Where required or indicated, provide a chain or other means to fix relative longitudinal position of outer and inner joint sections.

2.8.5 Gaskets

2.8.5.1 Elastomer Buna N

Sheet, 1/8 inch thick, conforming to ASTM D2000, Type 2BG410B14.

2.8.5.2 Elastomer Chloroprene

Sheet, 1/8 inch thick, conforming to ASTM D2000, Type 2BE410B14.

2.8.5.3 Rubber

Sheet, 1/8 inch thick red or black, natural, reclaimed, synthetic rubber or mixture thereof, conforming to ASTM D1330.

2.8.6 Protective Coating Materials

2.8.6.1 Baked Unmodified Phenolic

MIL-DTL-12276, Type II.

2.8.6.2 Epoxy Coating

Conform to MIL-PRF-23236, Type I, Class 1 or MIL-DTL-24441 system, Formula 150 green primer 3 mils, Formula 151 haze gray 3 mils, and Formula 152

white 3 mils.

2.8.6.3 Inorganic Zinc Coating

SSPC Paint 20, Type I-C (Self-cure type).

2.8.6.4 Galvanizing Repair Paint

Conform to MIL-P-21035.

2.8.7 Sealants

2.8.7.1 Elastomeric

Sealant specified in these specifications or referenced standards as elastomeric or without further qualification, must be silicone, polyurethane, polysulfide, polyisobutylene, or acrylic terpolymer suitable for the service. For sealing of nongasketed duct joints during fabrication or assembly, sealant must be polyurethane, acrylic terpolymer or polysulfide. Sealants must conform to the following:

- a. Silicone: Conforming to FS TT-S-001543, single component type, not requiring primed substrate, with manufacturer published estimated life of 30 years and a maximum 5 percent shrinkage when cured.
- b. Polyurethane: Conforming to ASTM C920, Type 2, Class A, single component type, not requiring primed substrate, with manufacturer published estimated life of 20 years and a maximum 10 percent shrinkage when cured.
- c. Polysulfide: Conforming to ASTM C920, Type 2, Class A, single component type, not requiring primed substrate, with manufacturer published estimated life of 20 years and a maximum 10 percent shrinkage when cured.
- d. Polyisobutylene/Butyl: Conforming to CID A-A-272, Type 1, single component type, not requiring primed substrate, with manufacturer published estimated life of 10 years and a maximum 15 percent shrinkage when cured.
- e. Acrylic Terpolymer: Conforming to ASTM C920, single component type, not requiring primed substrate, with manufacturer's published estimated life of 20 years and a maximum 10 percent shrinkage when cured.
- f. Provide sealants and non-aerosol adhesive products meeting either emissions requirements of CDPH SECTION 01350 (use the office or classroom requirements, regardless of space type) or VOC content requirements of SCAQMD Rule 1168 (HVAC duct sealants must be classified in the "Other" category within the SCAQMD Rule 1160 sealants table). Provide validation of indoor air quality for duct sealants.

2.8.7.2 Heat Shrinking over Round Exterior Duct

High molecular weight, irradiated polyethylene band with interior heat activated epoxy adhesive coating for heat shrinking and epoxy extrusion over round, exterior, duct joints.

2.8.7.3 Hard Cast Caulking for Exterior Ducts

Mineral and adhesive impregnated woven fiber tape with adhesive activator for exterior round or rectangular duct joints.

2.8.7.4 Caulking of Building Surface Penetration

Foamed silicones, two-component, fire-resistant, , low-exotherm, room temperature vulcanizing silicone.

2.9 SPECIALTIES

Steel, cast iron, stainless steel, nonferrous metal, or plastic to match duct construction, or as indicated.

2.9.1 Access Ports, Test

With gasketed screw cap and flange, to suit exhaust service, one inch nominal pipe size.

2.9.2 Damper Regulators

Incremental position indicating and locking type, with satin finish chrome plated, flush surface mounting cover and regulator box where concealment is required in finished spaces. For splitter dampers, provide splitter tip mounted trunnion brackets with self-locking screw regulator or rods with external swivel joint brackets.

2.9.3 Blast Gates

Provide means for locking in adjusted position with bolt and nut.

2.9.4 Cast Iron Access Door

Cast iron frame, hinged and gasketed cast iron door, quick closing clamps for watertight sealing, size as indicated.

2.10 SUPPORTS AND HANGERS

2.10.1 General Requirements for Supporting Elements

Provide ducting systems and equipment supporting elements including but not limited to building structure attachments; supplementary steel; hanger rods, stanchions and fixtures; vertical duct attachments; horizontal duct attachments; anchors; supports. Design supporting elements for stresses imposed by systems, with a minimum safety factor of 4.0 based on duct being 50 percent full of particulate conveyed. Supporting elements must conform to SMACNA 1403, SMACNA 1922, SMACNA 1520, SMACNA 1378, and NFPA 91, as applicable, and modified and supplementary requirements specified herein. Do not use weld studs and powder actuated anchoring devices to support mechanical systems components without prior approval.

2.10.2 Vertical Attachments

Provide in accordance with SMACNA Standards, except mill galvanized iron straps must be a minimum of one inch wide, 16 gage thick.

2.10.3 Horizontal Attachments

Provide as indicated in accordance with SMACNA Standards.

2.10.4 Supplementary Steel

Provide where required to frame structural members between existing members or where structural members are used in lieu of commercially rated supports. Such supplementary steel must be fabricated in accordance with the AISC 360.

2.10.5 Vibration Isolators

Provide vibration isolators with in-series, contained, steel springs, chloroprene elastomer elements, and fasteners for connecting to building structure attachments. Devices must be loaded by support system in operating condition to produce required static spring deflection without exceeding 75 percent of device maximum load rating.

2.11 DUCTWORK, DUST COLLECTION

2.11.1 General Requirements for Dust Collection Ductwork

Where specified or indicated fabricate system ductwork from black carbon steel, with welded seams and flanged and gasketed joints. Provide steel with a minimum of 70 percent recycled content. Provide data identifying percentage of recycled content of ductwork steel components. Construct duct to handle particulate with an influent loading of . Provide ductwork in accordance with best practice recommendations and requirements of SMACNA 1922 and SMACNA 1520, for Class I duct and requirements specified or indicated.

2.11.2 Fabrication of Dust and Fume Collection Ductwork

Provide indicated sizes, lengths and configuration without deviation unless otherwise approved. Assemble ductwork airtight as defined under paragraph DUCTWORK STRUCTURAL INTEGRITY AND LEAKAGE TESTING in this section and include necessary reinforcements, bracing, supports, framing, gasketing and fastening to guarantee rigid construction and freedom from vibration, airflow induced motion, and excessive deflection. For system, provide SMACNA Class 1 construction with any of the reference standard seams and connections being acceptable. For system, provide SMACNA Class 2 construction with welded duct and fitting seams and welded companion angle or Van-Stone flanges. Welding must conform to requirements specified herein. Provide flanges at branches where necessary for ease of access to equipment or maintenance disassembly, and where indicated. Provide elbows and fittings a minimum 2 gages heavier than straight ducts of equal diameter.

2.11.3 Radius Elbows

Fabricated from butt welded specified piece gore sections or from formed welded or seamless tubing to a minimum centerline radius of 2.0 diameters. Assemble, weld, and finish ground gore sections to eliminate internal projections. Construct gored elbow in accordance with the following:

<u>16 inches diameter and less</u>	<u>Over 16 inches diameter</u>
90 degree - 5 piece minimum	90 degree - 7 piece minimum
60 degree - 4 piece minimum	60 degree - 6 piece minimum
45 degree - 3 piece minimum	45 degree - 5 piece minimum
30 degree - 3 piece minimum	30 degree - 4 piece minimum
15 degree - 2 piece minimum	15 degree - 3 piece minimum

2.11.4 Flanged Joints

Gasketed with full face gaskets 1/8 inch thick red or black rubber as specified under paragraph MISCELLANEOUS MATERIALS in this section.

2.11.5 Access Doors

Provide hinged, gasketed, and fitted with snap-action closures access doors. Equip access door with gaskets of common weather stripping type, foamed, closed-cell, elastomer with pressure sensitive adhesive back. Provide cleanout adjacent to every bend and vertical riser. In horizontal duct runs, locate cleanout door with maximum of spacing of 12 feet for ducts 12 inches or less in diameter and 20 feet for larger ducts.

2.11.6 Flexible Connectors

Provide drawband secured flexible connectors, conforming to requirements specified under paragraph MISCELLANEOUS MATERIALS in this section, utilizing 1/8 inch thick reinforced elastomer, fabricated into a cylindrical shape by vulcanizing or otherwise bonding longitudinal seam.

2.12 PROTECTIVELY COATED STEEL DUCTS

Ductwork, Protectively Coated Steel, For Corrosive Fume and Vapor Exhaust:

2.12.1 General Requirements for Protectively Coated Steel Ductwork

Fabricate system ductwork from black carbon steel with welded seams, flanged and gasketed joints and protectively coated interior surfaces including flange faces, provide steel with a minimum of 70 percent recycled content. Provide data identifying percentage of recycled content of protectively coated steel ducts. Construct ductwork to handle fumes containing . Spiral welded duct is prohibited. Provided ductwork in accordance with best practice recommendations and requirements of SMACNA 1922 and SMACNA 1520, for Class IV duct.

2.12.2 Protective Coating

Provide and protective coatings as specified under PROTECTIVE COATING MATERIALS, a subparagraph of MISCELLANEOUS MATERIALS in this section. Provide coating to interior of duct and related fan surfaces. Coat exterior duct and related fan surfaces with same protective coating as specified for exterior surfaces inorganic zinc coating . Exterior fan surfaces must be finished protectively coated

2.12.3 Fabrication of Protectively Coated Ductwork

Construct protectively coated ductwork for corrosive fume and vapor exhaust in accordance with SMACNA 1922 and SMACNA 1520 and as specified herein. Provide indicated sizes, lengths and configuration without deviation, unless otherwise approved. Spiral welded duct is prohibited. Install ductwork to be water washable, watertight, self-draining, and airtight as defined under paragraph DUCTWORK STRUCTURAL INTEGRITY AND LEAKAGE TESTING in this section. Provide necessary reinforcements, bracing supports, framing, gasketing, and drainage provisions, and fastening to guarantee rigid construction and freedom from vibration, airflow induced motion, and excessive deflection. Rigid construction is required to prevent damage to or failure of protective coating during construction, transport, erection, and on-off system operation. Only companion angle flanged joints must be permitted. Weld ducting and fittings seams. Avoid seams in bottom 3 inches of ducting and in corners wherever practical by bending of corners and arranging seams high in the side sheets or top sheet. Cracks, laps, sharp inside corners, sharp sheared edges, weld "icicles," flux, pits, weld spatter, burrs, and similar defects which contribute to coating discontinuities must be eliminated by the following: a) welding continuously, b) grinding of metal flush with surface or to 1/32 inch radius or to maximum radius permitted by thinner metals, c) Utilizing other fabrication techniques and subsequent surface preparation abrasive blasting. Removed from the job site for repair rejected ducting not conforming to these requirements and which exhibit coating thickness deficiency. Welding must conform to requirements specified herein. Continuously weld companion flange angles to the inside of the duct and intermittently weld with one inch welds every 4 inches on outside of duct. Intermittently weld girth and transverse reinforcements to duct surface for one inch on 6 inch centers or spot welded on 4 inch centers. Weld and grind flange and reinforcement angles at corners or ends to form continuous frames. Provide flanges at branches, where necessary for ease of access to equipment or maintenance disassembly, and where indicated. Limit duct lengths in accordance with size, to permit complete and ready access for welding, grinding, blasting, coating, coating continuity checking and testing, and visual inspection during fabrication and immediately prior to erection.

2.12.4 Radius Elbows

Fabricated radius elbows from butt welded specified piece gore sections or from formed welded or seamless tubing to a minimum centerline radius of 2.0 diameters and preferably 2.5 times the duct diameter. Assemble, weld, and finish ground gore sections to prevent internal crevices and projections. Construct gored elbow in accordance with the following:

<u>16 inches diameter and less</u>	<u>Over 16 inches diameter</u>
90 degree - 5 piece minimum	90 degree - 6 piece minimum
60 degree - 4 piece minimum	60 degree - 5 piece minimum
45 degree - 3 piece minimum	45 degree - 4 piece minimum

<u>16 inches diameter and less</u>	<u>Over 16 inches diameter</u>
30 degree - 3 piece minimum	30 degree - 3 piece minimum
15 degree - 2 piece minimum	15 degree - 2 piece minimum

2.12.5 Flanged Joints

Gasketed with full-face gaskets which are one-piece, heat, adhesive or solvent vulcanized, or bonded and assembled to prevent drainage and limit extrusion or cavity at joint.

2.12.6 Access and Cleanout Door Openings

Provide access plates upstream and downstream of equipment installed in ductwork, at locations to facilitate duct cleaning (such as in horizontal runs, near elbow junctions, and vertical runs), and where indicated. For ducts 12 inches diameter or less, locate cleanout or access openings a minimum of 12 feet apart. Provide 10 by 12 inches minimum size access opening; unless otherwise indicated or prevented by duct dimension. Locate opening a minimum of 3 inches from bottom of duct. Frame access openings by welded and ground miter joint 3/16 inch thick strap iron, or angle iron, with 1/4 inch stainless steel bolt or stud assembly to duct on 4 inch centers. Fabricate plates out of 300 series corrosion-resistant steel or polyvinyl chloride faced sheet backed by 16 gage sheet metal, reinforced as required for larger sizes, or constructed of heavier gage metal. Ensure only corrosion resistant materials are expose to duct interior. Provide one "U" handle on access plates through 10 by 12 inches and two "U" handles on larger sizes. Locate access openings at points which will permit ready access to duct internals with no duct cutting. Where access through equipment or access doors specified herein is not available at a specific point, provide 8 inch diameter gasketed access plates spaced on maximum 10 foot centers. Where penetration of duct surfaces is approved or specified, provide 300 series corrosion resistant steel fastener assemblies. Provide hex type, cadmium plated flange fastener bolts and nuts and 1/8 inch thick acid resistant chloroprene joint gaskets.

2.13 STACKHEADS

Provide SMACNA 1403 no loss type stackheads for vertical discharge to the atmosphere unless indicated otherwise. Weather caps are prohibited. Provide bracing or guy wires for wind loads on stacks as indicated. Discharge stacks should be vertical and terminate at a point where height or velocity prevents reentry of exhaust air.

PART 3 EXECUTION

3.1 INSTALLATION

3.1.1 Installation Requirements

Install in accordance to NFPA 91, and SMACNA 1922, and SMACNA 1520. Provide mounting and supports for equipment, ductwork, and accessories, including structural supports, hangers, vibration isolators, stands, clamps and brackets, access doors, blast gates, and dampers. Install accessories in accordance with the manufacturer's instructions. Construct

positive pressure duct inside buildings airtight.

3.1.1.1 Wood Facilities

For facilities, conform to NFPA 664.

3.1.1.2 Aluminum Facilities

For aluminum processing finishing facilities, conform to NFPA 65.

3.1.2 Electrical Ground Continuity

Where electrical ground continuity is required, provide brazed connection insulated, multi-strand, copper wire jumpers across points of discontinuity. Provide connection to ground and continuity testing as part of the work of Division 16.

3.1.3 Miscellaneous Sheet Metal Work

Provide and , fabricated from mill galvanized steel , as indicated. Sheet metal thickness, reinforcement and fabrication, where not indicated, must conform to SMACNA 1403.

3.1.4 Building Penetrations

3.1.4.1 General Penetration Requirements

Provide properly sized, fabricated, located, and trade coordinated sleeves and prepared openings, for duct mains, branches, and other item penetrations, during the construction of the surface to be penetrated. Provide sleeves for round duct 15 inches and smaller and prepared openings for round duct larger than 15 inches and square or rectangular duct. Fabricate sleeves, except as otherwise specified or indicated, from 20 gage, 0.0396 inch thick mill galvanized sheet metal. Sleeves penetrating load bearing surfaces must be standard weight galvanized steel pipe. Provide roof penetrations as shown in SMACNA 1403.

3.1.4.2 Framed Opening

Provide framed openings in accordance with approved shop drawings. Refer to paragraph FIRE DAMPERS in this section, for related work.

3.1.4.3 Clearances

Provide a minimum one inch clearance between penetrating and penetrated surfaces. Fill clearance space with bulk fibrous glass or mineral wool and seal and close.

3.1.4.4 Tightness

Penetration must be weathertight .

3.1.4.5 Sealants

Provide sealant of elastomeric type or foamed silicone type, as specified under paragraph SEALANTS in this section. Apply to oil free surfaces to a minimum 3/8 inch depth.

3.1.4.6 Closure Collars

Provide a minimum 4 inches wide, unless otherwise indicated, for exposed ducts and items on each side of penetrated surface, except where equipment is installed. Install collar tight against the surface and fit snugly around penetrating item without contact. Grind sharp edges smooth to prevent damage to penetrating surface. Fabricate collars for round ducts 15 inches in diameter or less from 20 gage, 0.0396 inch nominal thickness, mill galvanized steel. Attach collars a minimum of 4 fasteners to where the opening is 12 inches in diameter or less, and a minimum of 8 fasteners where the opening is 20 inches in diameter or less. Fabricate collars for square and rectangular ducts with a maximum side of 15 inches or less from 20 gage, 0.0396 inch nominal thickness, mill galvanized steel. Fabricate collars for round, square, and rectangular ducts with minimum dimension over 15 inches from 18 gage, 0.0516 inch in nominal thickness, mill galvanized steel. Install collars with fasteners a maximum of 6 inches on center. Where penetrating items are irregularly shaped and where approved, smoothly finished, fire-retardant, foamed silicone elastomer may be utilized without closure collar.

3.1.5 Installation of Fire Dampers

Install fire dampers at locations indicated. Provide units and connecting ductwork in accordance with applicable provisions of NFPA 91, AMCA 500-D and UL 33, and as indicated. Install retaining angles, sleeves, break-away connections, and duct access doors at each damper, as required. Minimum thickness of sleeves must be 14 gage, except as otherwise indicated. Duct access doors must be hinged and fitted with UL listed glass viewing port assembly. Prior to acceptance, simulate conditions to cause each unit to function automatically. Apply safe, nonflame, heat source to fusible links and replace test activated fusible links.

3.1.6 Installation of Flexible Connectors

Flexibly connect duct connected and vibration isolated fans, ducts crossing building expansion joints and specified or indicated components, except where direct connections are specified or indicated. When fans are started, stopped, or operating, flexible connector surfaces must be curvilinear, free of stress induced by misalignment or fan reaction forces, and must not transmit vibration. Leakage must not be perceptible to the hand when placed within 6 inches of the flexible connector surface or joint. Provide a minimum of 6 inches and a maximum of 2 feet active length with a minimum of one inch of slack, secured at each end by folding in to 24 gage sheet metal or by metal collar frames.

3.1.7 Installation of Supports

3.1.7.1 Selection

Select duct and equipment support system taking into account the best practice recommendations and requirements of SMACNA 1922, SMACNA 1520, and NFPA 91; location and precedence of work under other sections; interferences of various piping and electrical work; facility equipment; building configuration; structural and safety factor requirements; vibration and imposed loads under normal and abnormal service conditions. Indicated support sizes, configurations, and spacings are the minimal type of supporting component required for normal loads. Where installed loads are excessive for the normal support spacings, provide heavier duty

components or reduce the element spacing. After system start-up, replace or correct support elements which vibrate and cause noise or possible fatigue failure. Exercise special care to prevent cascading failure.

3.1.7.2 General Requirement for Supports

Securely attach supporting elements to building structural steel or structural slabs. Where supports are required between building structural members provide supplementary structural steel as specified for work under this section. On submittals show location of supports and anchors and loads imposed on each point of support or anchor. Do not hang ductwork or equipment from piping, or other ducts or equipment. Attach supports to structural framing member and concrete slab. Do not anchor supports to metal decking unless a means is provided and approved for preventing the anchor from puncturing the metal decking. Where supports are required, between structural framing members, provide suitable intermediate metal framing. Where C-clamps are used, provide retainer clips. A maximum span of 10 feet must exist between any two points, with lesser spans as specified or as required by duct assemblies, interferences, and loads imposed or permitted. Provide a minimum one set of two vertical support elements for each point of support and each length of duct, except as otherwise specified. Install supports on both sides of all duct turns, branch fittings, and transitions. Cross-brace hangers sufficiently to eliminate sway. Perforated strap hangers are prohibited. Where ductwork system contains heavy equipment, hang such equipment independently of the ductwork. Duct supports must be vibration isolated from structure at points indicated.

3.1.7.3 Methods of Attachment

Clamp, or weld when approved, attachment to building structural steel in accordance with AWS D1.1/D1.1M. Construct masonry anchors selected for overhead applications of ferrous materials only. Install masonry anchors in rotary, non-percussion, electric drilled holes. Self-drilling anchors may be used provided masonry drilling is performed with electric hammers selected and applied in such a manner as to prevent concrete spalling or cracking. Pneumatic tools are prohibited.

3.1.8 Welding

Welding test agenda must be done in accordance with the applicable provisions of AWS D1.1/D1.1M and AWS D1.3/D1.3M.

3.1.9 Test Ports

Provide test access ports at points required for work under paragraph TESTING, ADJUSTING, AND BALANCING in this section. Locate test ports in straight duct as far as practical downstream of fans, change of direction fittings, takeoffs, interior to duct accessories, and like turbulent flow areas.

3.1.10 Ductwork Cleaning

Protect duct openings from construction debris using temporary caps, flanges, or other approved means. Clean ductwork in accordance with manufacturer's recommendations and the North American Insulation Manufacturers Association (NAIMA) Guide on Cleaning of Duct Board Materials.

Clean dirty duct interior with high velocity water and oil-free air streams or by vacuum cleaning as required by project conditions. After

construction is complete but accessible and prior to acceptance, remove all construction debris from exterior surfaces. Do not close duct inspection ports until inspected by the Contracting Officer.

3.1.11 Factory and Field Painting and Finishing

3.1.11.1 Factory Work

Factory finish interior ferrous metal and other specified metallic equipment and component surfaces with manufacturer's standard surface preparation, primer, and finish coating. Factory finish exterior to building space ferrous metal surfaces and other exterior to building and interior to building metallic or nonmetallic surfaces with specified protective coating system in accordance with the paragraph PROTECTIVE COATING MATERIAL in this section and otherwise with manufacturer's standard surface preparation, primer and finish which meet the requirements of paragraph CORROSION PREVENTION.

3.1.11.2 Field Work

Touch-up or if necessary, repaint factory applied finishes which are marred, damaged, or degraded during shipping, storage, handling, or installation to match the original finish. Clean and prime field or shop fabricated ferrous metals required for the installation specified under this section in accordance with the applicable provisions of Section 09 90 00 PAINTS AND COATINGS. Painting of surfaces not otherwise specified and finish painting of items only primed at the factory or elsewhere, are specified as part of the work under Section 09 90 00 PAINTS AND COATINGS.

3.2 TESTING, ADJUSTING, AND BALANCING

3.2.1 Ductwork Structural Integrity and Leakage Testing

Inspect and test systems pressure rated higher than 2 inches water gage for structural integrity and leakage as systems or sections during construction but after erection, as work progresses, in system or section lengths not exceeding 100 feet. Test for structural integrity at percent in excess of system fan positive or negative total pressure. Test for leakage at 2 percent in excess of system fan positive or negative total pressure. Leakage test procedure and apparatus must be in accordance with SMACNA 1972 CD. Total leakage, prorated to length of duct under test, must not exceed one percent of system capacity. Do not permit leakage in positive pressure ducts in buildings carrying flammable or toxic materials.

3.2.2 Power Transmission Components Adjustment

Test and adjust V-belts and sheaves for proper alignment and tension preliminary to operation and after 72 hours of operation at final speed, in the presence of the Contracting Officer. Belts on drive side must be uniformly loaded, not bouncing. Align direct-drive couplings to less than half of manufacturer's allowable range of misalignment.

3.2.3 Preliminary Tests

Conduct an operational test on the entire exhaust duct systems, components, and equipment for a period of not less than 6 hours after power transmission components are adjusted. Replace filters, if any, after preliminary tests and prior to conducting final acceptance tests.

3.2.4 Testing, Adjusting, and Balancing Work

Perform work in accordance with the applicable and recommended procedures of: ACGIH-2092S. Provide apparatus, certified, calibrated, instrumentation including that to measure sound levels, motor current, and power factor. Unless approved otherwise, instruments must be limited to manometers and approved aneroid type gages (such as a Magnehelic). Velometers may be used for low velocity measurements if approved by the Contracting Officer.

3.2.5 Systems Volume Acceptance Criteria

Systems final volume must be within the following limits:

Fan: Plus 10 percent, minus zero percent of design volume at design temperature

Hood or Equipment: Plus or minus 5 percent of design volume at design temperature

Note: Tolerances must be taken on clean or dirty conditions as indicated on the drawings.

3.2.6 Sound Level Tests

Report to the Contracting Officer in writing, sound levels higher than 84 dBA at hoods or at workers' normal operating positions at equipment in addition to being included in the required test reports.

3.3 SYSTEMS OPERATION DEMONSTRATION

After systems and equipment testing, adjusting, and balancing has been completed and accepted, demonstrate the complete and correct functioning of systems equipment and controls by operation through normal ranges and sequences, and by simulation of abnormal conditions, including the manual tripping of fire dampers. Manually and automatically cause every device to function as intended. Readjust, as necessary, any settings and after sufficient operating time, but not less than 6 hours, verify ability of equipment and controls to establish and maintain stable and accurate operation and required system performance. Note any abnormal deviations, such as excessive vibration, noise, and heat, binding damper mechanisms, and incorrect fan rotation. Make any necessary repairs, replacements or adjustments.

-- End of Section --

SECTION 23 37 13.00 40

DIFFUSERS, REGISTERS, AND GRILLES

08/22

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE 113	(2013) Method of Testing for Room Air Diffusion
ASHRAE EQUIP IP HDBK	(2012) Handbook, HVAC Systems and Equipment (IP Edition)
ASHRAE FUN IP	(2021) Fundamentals Handbook, I-P Edition

1.2 ADMINISTRATIVE REQUIREMENTS

Section 23 30 00 HVAC AIR DISTRIBUTION applies to work specified in this section.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Material, Equipment, and Fixture Lists; G

Records of Existing Conditions

SD-02 Shop Drawings

Fabrication Drawings

Installation Drawings

SD-03 Product Data

Equipment and Performance Data

SD-04 Samples

Manufacturer's Standard Color Chart

SD-10 Operation and Maintenance Data

Type TS Supply Troffer

Type TSR Combination Supply and Return Troffer

PART 2 PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

Certify air diffusion devices having been tested and rated in accordance with Chapter 19-ASHRAE EQUIP IP HDBK, Chapter 16-ASHRAE FUN IP, and ASHRAE 113, where such certification is required.

Submit equipment and performance data for air-diffusion devices consisting of sound data in terms of Noise Criteria (NC) index for the capacity range of the device.

2.2 COMPONENTS

2.2.1 Air Diffusion Device Construction

Preclude flutter, rattle, or vibration on air-diffusion device construction and mounting. Modify devices and provide accessories necessary for mounting in indicated surface construction.

Select color from manufacturer's standard color chart which indicates the manufacturer's standard color selections and finishes for air-diffusion devices.

Provide supply diffusers with combination damper and equalizing grid. Ensure dampers are extracting-splitter type, except as otherwise indicated. Equalizing grids shall consist of individually adjustable vanes designed for equalizing airflow into diffuser neck and providing directional control of airflow.

Ensure air-diffusion device volume and pattern adjustments can be made from the face of the device. Make volume adjustments by removable key .

Provide gaskets for supply-terminal air devices mounted in finished surfaces.

Include within the material, equipment, and fixture lists the manufacturer's style or catalog numbers, specification and drawing reference numbers, warranty information, and fabrication site information.

Submit records of existing conditions consisting of the results of Contractor's survey of work area conditions and features of existing structures and facilities within and adjacent to the jobsite. Commencement of work constitutes acceptance of existing conditions.

Submit fabrication drawings for air-diffusion devices consisting of fabrication and assembly details to be performed in the factory.

2.2.2 Types of Air Diffusion Devices

2.2.2.1 Type DRA

Provide type DRA supply diffuser, round with five or more expanding cones

with beaded edges to provide hemispherically diffused discharge air. Arrange cones to provide a minimum of four air paths which simultaneously diffuse air at 20 to 50 feet per minute (fpm) and aspirate room air at 25 to 35 percent of discharge volume.

Provide aluminum diffuser with baked enamel finish.

Provide antismudge rings and extended cones.

2.2.2.2 Type DRB

Provide type DRB supply diffuser, round with four more expanding cones to provide hemispherically diffused discharge air. Arrange cones to provide a minimum of three air paths which simultaneously diffuse air at 20 to 50 fpm. Provide a pattern adjustment range from horizontal to downward projection, and any intermediate point, when mounted on exposed ductwork.

Provide aluminum diffuser with baked enamel finish.

Provide Integral antismudge rings and extended cones.

2.2.2.3 Type DRC

Provide type DRC combination supply and return diffuser, round with four expanding cones. Arrange cones to provide one return air path and two supply air paths. Provide a butterfly supply-air damper and an annular return-air damper. Provide a baked enamel finish

2.2.2.4 Type DRE

Provide type DRE supply diffuser, round with three expanding cones to provide discharge air paths, minimally, two-position adjustable for horizontal or vertical discharge. Provide a baked enamel finish.

2.2.2.5 Type DRH

Provide type DRH supply diffuser, half-round with four semiconical expanding members to discharge diffused air in a 180-degree pattern. Arrange cones to provide a minimum of three air paths which simultaneously diffuse air at 20 to 50 fpm. Provide opposed-blade volume control.

Provide a baked enamel finish.

2.2.2.6 Type DP Series

Provide type DP series supply diffuser with a square , perforated, face plate with opposed blade volume control, white baked enamel exterior finish, and black matte finish on exposed-to-view interior surface. Provide hinges and latches for removal of perforated face plates to allow for cleaning and adjustment of baffle or damper.

Provide two-way opposed deflection.

2.2.2.7 Type DLB

Provide type DLB supply diffuser, linear bar type, frame mounted, with extruded-aluminum bar and frame.

Ensure bars are 1/4 inch thick by 3/4 inch high, 1/2 inch on center,

pencilproof spacing, with zero degree bar deflection angle.

For floor- and sill-mounted diffusers provide heavy-duty reinforced construction to carry loads of not less than 100 pounds per square foot.

Provide continuous length diffuser with hairline butt joints.

Provide mitered end caps where diffuser run terminates.

Provide opposed-blade type dampers.

Provide an integral, pivoted, bar-type access door where indicated.

Provide straightening grids where indicated.

2.2.2.8 Type DLS

Provide type DLS supply diffuser, linear slot type, extruded aluminum construction, with fully adjustable integral air pattern and volume control vanes that deflect air pattern from horizontal along ceiling to straight down. Ensure any intermediate setting and a pattern control element that permits complete blanking-off of slot.

Slot width: 3/4 inch.

Provide number of slots per unit run as indicated.

Align butts in continuous runs for hairline joints.

Butt ends of diffuser against walls without mitered end caps. Provide end caps where slot terminates.

Provide exposed-to-view part of frame with anodized aluminum, and all interior exposed-to-view components with a black matte finish.

2.2.2.9 Type DSA

Provide type DSA supply diffuser, square with four expanding flared members to provide radially diffused discharge air. Arrange flared members to provide a minimum of four air paths which simultaneously diffuse air at 20 to 50 fpm. Include pattern adjustments horizontal, vertical projection, and an intermediate position or range.

Provide a baked enamel finish.

2.2.2.10 Type GS

Provide type GS supply grilles double deflection type with adjustable face bars parallel to short dimension and adjustable rear bars parallel to long dimension.

Provide a baked enamel finish.

2.2.2.11 Type GSP

Provide type GSP series supply grille with a square, perforated face plate, white baked enamel exterior finish, black matte finish on exposed-to-view interior surface for lay-in or surface mounting. Perforated face plate to be removeable, hinged or unlatched, for cleaning.

Provide aluminum construction.

2.2.2.12 Type GEP

Provide type GEP series return or general exhaust grille with a square, perforated face plate, white baked enamel exterior finish, black matte finish on exposed-to-view interior surface for lay-in or surface mounting. Perforated face plate to be removeable, hinged or unlatched for cleaning.

Provide aluminum construction.

2.2.2.13 Type GSE

Provide type GSE series return or general exhaust grille with a square, eggcrate face with 1/2 by 1/2 by 1/2 inch aluminum core, white baked enamel exterior finish, black matte finish on exposed-to-view interior surface for lay-in mounting.

Provide aluminum border.

2.2.2.14 Type GR

Provide type GR return grilles, single deflection type with fixed face bars.

Provide grilles installed in vertical surfaces with horizontal face bars set downward at 45 degrees from vertical.

Provide grilles installed in horizontal surfaces with face bars straight and parallel to short dimension.

Provide aluminum construction.

2.2.2.15 Type GCA

Provide type GCA with an individually adjustable, horizontal, curved-blade grilles and a one-way pattern.

Provide aluminum construction.

2.2.2.16 Type GCB

Provide type GCB with an individually adjustable, vertical, curved-blade grilles and a one-way pattern.

Provide aluminum construction.

2.2.2.17 Type GCD

Provide type GCD with an individually adjustable, vertical, curved-blade grilles and a two-way pattern.

Provide aluminum construction.

2.2.2.18 Type GCE

Provide type GCE with an individually adjustable, vertical and horizontal, curved-blade grilles and a three-way pattern.

Provide aluminum construction.

2.2.2.19 Type GCF

Provide type GCF with an individually adjustable, vertical and horizontal, curved-blade grilles and a four-way pattern.

Provide aluminum construction.

2.2.2.20 Type RS

Provide type RS supply register, double-deflection type, with adjustable face bars parallel to short dimension and adjustable rear bars parallel to long dimension with opposed-blade type dampers.

Provide aluminum construction.

2.2.2.21 Type RR

Provide type RR return register, single-deflection type with fixed face bars with opposed-blade dampers.

Provide registers installed in vertical surfaces with horizontal face bars set downward at approximately 45 degrees from vertical.

Provide registers installed in horizontal surfaces with face bars set straight and parallel to short dimension.

Provide a baked enamel finish.

2.2.2.22 Type RCA

Provide type RCA with an individually adjustable, horizontal, curved-blade register and a one-way pattern with opposed-blade damper.

Provide aluminum construction.

2.2.2.23 Type RCB

Provide type RCB with individually adjustable, vertical, curved-blade register and a one-way pattern with opposed blade damper.

Provide aluminum construction.

2.2.2.24 Type RCC

Provide type RCC with an individually adjustable, horizontal, curved-blade register and a two-way pattern with opposed blade damper.

Provide aluminum construction.

2.2.2.25 Type RCD

Provide type RCD with an individually adjustable, vertical, curved-blade register and a two-way pattern with opposed blade damper.

Provide aluminum construction.

2.2.2.26 Type RCE

Provide type RCE with an individually adjustable, vertical and horizontal, curved-blade register and a three-way pattern with opposed-blade damper.

Provide aluminum construction.

2.2.2.27 Type RCF

Provide type RCF with an individually adjustable, vertical and horizontal, curved-blade register and a four-way pattern with opposed-blade damper.

Provide aluminum construction.

2.2.2.28 Type TS

Provide type TS supply troffer complete assembly as specified in Section 26 51 00 INTERIOR LIGHTING and as indicated. Install air handling section of unit under this section.

2.2.2.29 Type TR

Provide type TR return troffer conforming to requirements for Type TS supply troffer.

2.2.2.30 Type TSR

Provide type TSR combination supply and return troffer assembly as specified in Section 26 51 00 INTERIOR LIGHTING and as indicated. Install air handling section of unit under this section.

PART 3 EXECUTION

3.1 INSTALLATION

Install equipment as indicated and specified and in accordance with manufacturer's recommendations.

Mount wall-mounted supply registers 6 inches below ceiling.

Submit installation drawings for air-diffusion devices. Indicate on drawings overall physical features, dimensions, ratings, service requirements, and equipment weights.

Unless otherwise indicated, size ductwork drop to diffusers or grilles to match unit collar sizes.

Seal connections between ductwork drops to diffusers or grilles airtight.

Support independently diffusers and grilles for T-bar mounting that exceed weight limit of ceiling suspension system in which they are to be installed.

3.1.1 Operations and Maintenance Manuals

Provide operation and maintenance manuals consistent with manufacturer's standard brochures, schematics, printed instructions, general operating procedures and safety precautions.

-- End of Section --

SECTION 23 80 20.00 10

GAS-FIRED HEATING EQUIPMENT
05/20

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI Z21.66/CGA 6.14 (2015; R 2020) Automatic Vent Damper Devices for Use with Gas-Fired Appliances

ANSI Z21.86/CSA 2.32 (2016) Vented Gas-Fired Space Heating Appliances

ANSI Z83.4/CSA 3.7 (2017; R 2022) Non-Recirculating Direct Gas-Fired Heating and Forced Ventilation Appliances for Commercial and Industrial Application

ANSI Z83.8/CSA 2.6 (2016; R 2021) Gas Unit Heaters, Gas Packaged Heaters, Gas Utility Heaters, and Gas-Fired Duct Furnaces

ANSI Z83.19/CSA 2.35 (2017; R 2022) Gas-Fired High-Intensity Infrared Heaters

CSA GROUP (CSA)

CSA Directory (updated continuously online) Product Index

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA MG 1 (2021) Motors and Generators

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 54 (2024) National Fuel Gas Code

NFPA 211 (2019) Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances

UNDERWRITERS LABORATORIES (UL)

UL FLAMMABLE & COMBUSTIBLE (2012) Flammable and Combustible Liquids and Gases Equipment Directory

1.2 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the

Sustainability eNotebook, in conformance to Section 01 33 29
SUSTAINABILITY REPORTING. Submit the following in accordance with Section
01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Detail Drawings
Installation

SD-03 Product Data

Spare Parts

SD-06 Test Reports

Testing, Adjusting, and Balancing

SD-10 Operation and Maintenance Data

Operation and Maintenance Instructions

1.3 QUALITY ASSURANCE

Submit detail drawings consisting of illustrations, schedules, performance charts, instructions, brochures, diagrams, and other information to illustrate the requirements and operation of the system. Detail drawings for space heating equipment, controls, associated equipment, and for piping and wiring. Show proposed layout and anchorage of equipment and appurtenances, and equipment relationship to other parts of the work including clearances for maintenance and operation.

1.4 DELIVERY, STORAGE, AND HANDLING

Protect all equipment delivered and placed in storage from weather, humidity and temperature variations, dirt and dust, or other contaminants.

1.5 EXTRA MATERIALS

Submit spare parts data for each different item of material and equipment specified, after approval of the detail drawings, and not later than 2 months prior to the date of beneficial occupancy. Include in the data a complete list of parts and supplies, with current unit prices and source of supply.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

2.1.1 General

Provide materials and equipment which are standard products of a manufacturer regularly engaged in manufacturing of the products and that essentially duplicate equipment that has been in satisfactory use at least 2 years prior to bid opening. All gas fired appliances must meet the requirements of NFPA 54.

2.1.2 Nameplates

Secure a plate to each major component of equipment containing the

manufacturer's name, address, type or style, model or serial number, and catalog number. Also, affix an ENERGY STAR label as applicable.

2.1.3 Equipment Guards

Completely enclose or guard belts, pulleys, chains, gears, couplings, projecting setscrews, keys, and other rotating parts so located that any person may come in close proximity thereto. Guard or cover high-temperature equipment and piping so located as to endanger personnel or create a fire hazard with insulation of type specified for service.

2.2 ELECTRICAL WORK

Provide electrical motor driven equipment complete with motors, motor starters, and controls. Provide motors conforming to NEMA MG 1. Provide electrical equipment and wiring accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide electrical characteristics as specified or indicated. Provide premium efficiency integral size motors in accordance with NEMA MG 1. Provide motor starters complete with thermal overload protection and other appurtenances necessary for the motor control specified. Each motor must be of sufficient size to drive the equipment at the specified capacity without exceeding the nameplate rating of the motor. Manual or automatic control and protective or signal devices required for the operation specified and any control wiring required for controls and devices specified, but not shown, must be provided.

2.3 HEATERS

Equip heaters for and adjust to burn natural gas. Provide each heater with a gas pressure regulator that will satisfactorily limit the main gas burner supply pressure. Heaters must have an intermittent or interrupted electrically ignited pilot or a direct electric ignition system. Provide safety controls that conform to the ANSI standard specified for each heater. Furnish mounting brackets and hardware by the heater manufacturer and factory finish to match the supported equipment.

2.3.1 Direct Fired Make-Up Air Heaters

Furnish heaters in accordance with ANSI Z83.4/CSA 3.7. Direct fired make-up air heaters use outside air directly ducted to the heater. The products of combustion generated by the heater are released into the outside air stream being heated. Equip heaters with motorized inlet dampers, air filters, and bird screen. Provide modulating gas control valve. Maximum air temperature rise during minimum burner fire must be 7 degrees F. Fan must be variable speed. Provide weatherized outdoor heaters with manufacturer's standard exterior finish for outdoor units. Provide motorized outlet dampers that close when the unit is shut down. Dampers must be interlocked to prevent burner operation when dampers are closed. Provide heaters with a space thermostat, a low limit air stream thermostat, and an ambient air thermostat. The space thermostat must control the gas control valve. Provide low limit air stream thermostat to shut down the entire unit if the discharge air temperature drops below the space thermostat setting. Provide ambient air thermostat to shut down the burner if the outside air exceeds the space thermostat setting.

2.3.2 Indirect Fired Make-Up Heaters

Provide heaters in accordance with ANSI and CSA Standards. Equip heaters with motorized inlet dampers, duct collar, and air filters. Provide

modulating gas control valve. Maximum air temperature rise during minimum burner fire must be 7 degrees F. Fan must be two speed, with low speed approximately two-thirds of high speed. Provide motorized inlet dampers that close when the unit is shut down. Dampers must be interlocked to prevent burner operation when dampers are closed. Provide heaters with a space thermostat, a low limit air stream thermostat, and an ambient air thermostat. The space thermostat must control the modulating gas control valve. Provide low limit air stream thermostat to shut down the entire unit if the discharge air temperature drops below the space thermostat setting. Provide ambient air thermostat to shut down the burner if the outside air exceeds the space thermostat setting.

2.3.3 Unit Heaters

Provide heaters conforming to requirements of ANSI Z83.8/CSA 2.6. Provide aluminized steel or stainless steel heat exchangers. Equip air discharge section with adjustable horizontal louvers. Fan shafts must be either directly connected to the driving motor, or indirectly connected by multiple V-belt drive. Fans in one unit must be of the same size. Furnish power-vented heaters, suitable for sidewall vent discharge and single-wall-thickness vent piping. Provide heaters that have automatic ignition. Heaters must employ metered combustion air with enclosed draft diverter (no open flue collar). Provide heaters with a space thermostat which controls both unit's fan and burner.

2.3.4 Wall Furnace

Provide gravity wall furnace in accordance with ANSI Z21.86/CSA 2.32 and as indicated. Provide a space thermostat which controls both the unit's fan and burner.

2.3.5 Duct Furnace

Provide duct furnace in accordance with ANSI Z83.8/CSA 2.6. Provide power-vented furnace, suitable for sidewall vent discharge and single wall thickness vent piping. Provide furnace with automatic ignition. Furnace must employ metered combustion air with enclosed draft diverter (no open flue collar). Provide stainless steel furnace heat exchangers. Provide furnace with minimum steady state thermal efficiency of 80 percent at maximum rated capacity and 75 percent at minimum rated capacity that is provided and allowed by the controls. Provide furnace with a space thermostat which controls the unit's burner.

2.3.6 Infrared Heaters

Furnish heaters conforming to the requirements of ANSI Z83.19/CSA 2.35 and vented type. Vented heaters must be vented to the outside atmosphere. Heater style must be tubular type. Reflector shape must be parabolic. Provide heaters with space thermostats which control the unit's burner. Cover thermostats located in the direct radiation pattern with a metal shield.

2.4 THERMOSTATS

Provide adjustable electric or electronic thermostats. Include control wiring required to complete the space temperature control system. Provide thermostats that have a 3 degree F differential and a set point range of 40 to 75 degrees F. Provide two stage thermostats.

2.5 VENT PIPING

Provide vent piping conforming to the requirements of NFPA 54. Plastic material polyetherimide (PEI) and polyethersulfone (PES) are forbidden to be used for vent piping of combustion gases.

2.6 ELECTRIC AUTOMATIC VENT DAMPERS

Provide electric automatic vent dampers conforming to the requirements of ANSI Z21.66/CGA 6.14 and provide in the vents of heaters except unvented infrared heaters using indoor air for combustion air.

2.7 INSULATION

Provide insulation for piping and equipment and application in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.8 FACTORY FINISHES

Equipment and component items, when fabricated from ferrous metal, must be factory finished with the manufacturer's standard finish.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming thoroughly familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before performing any work.

3.2 INSTALLATION

install equipment as indicated and in accordance with the recommendations of the equipment manufacturer and the listing agency, except as otherwise specified.

3.2.1 Heating Equipment

Install heaters with clearance to combustibles, complying with minimum distances as determined by CSA Directory, UL FLAMMABLE & COMBUSTIBLE and as indicated on each heater approval and listing plate. Support heaters independently from the building structure, as indicated, but not relying on suspended ceiling systems for support.

3.2.2 Vents

Locate vent dampers, piping and structural penetrations as indicated. Perform vent damper installation in conformance to ANSI Z21.66/CGA 6.14. Extend vent pipes, where not connected to a masonry chimney conforming to NFPA 211, through the roof or an outside wall and terminate, in compliance with NFPA 54. Provide vents passing through waterproof membranes with the necessary flashings to obtain waterproof installations.

3.2.3 Gas Piping

Connect gas piping as indicated, complying with the applicable requirements at Section 23 11 20 FACILITY GAS PIPING.

3.3 TRAINING

Conduct a training course for the maintenance and operating staff. The training period of 2 hours normal working time must start after the system is functionally complete but before the final acceptance tests. Give the Contracting Officer at least two weeks advance notice of such training. Include all of the items contained in the approved operation and maintenance instructions as well as demonstrations of routine maintenance operations. Submit 6 complete copies of operating instructions outlining the step-by-step procedures required for system startup, operation and shutdown. Include the manufacturer's name, model number, service manual, parts list, and brief description of all equipment and basic operating features. Submit 6 complete copies of maintenance instructions listing routine maintenance, possible breakdowns, repairs and troubleshooting guide. Include simplified piping, wiring, and control diagrams for the system as installed.

3.4 TESTING, ADJUSTING, AND BALANCING

Perform testing, adjusting, and balancing as specified in Section 23 05 93 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS. Submit test reports in booklet form showing all field tests performed to adjust each component and all field tests performed to prove compliance with the specified performance criteria, upon completion and testing of the installed system. Indicate the final position of controls.

-- End of Section --

SECTION 23 81 00

DECENTRALIZED UNITARY HVAC EQUIPMENT
05/18, CHG 1: 02/21

PART 1 GENERAL

1.1 RELATED REQUIREMENTS

Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND METHODS, applies to this section with the additions and modifications specified herein.

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC. (AMCA)

AMCA 500-D (2018) Laboratory Methods of Testing
Dampers for Rating

AMCA 500-L (2015) Laboratory Methods of Testing
Louvers for Rating

AIR-CONDITIONING, HEATING AND REFRIGERATION INSTITUTE (AHRI)

AHRI 540 (2015) Performance Rating Of Positive
Displacement Refrigerant Compressors And
Compressor Units

AHRI 700 (2016) Specifications for Fluorocarbon
Refrigerants

ANSI/AHRI 210/240 (2008; Add 1 2011; Add 2 2012) Performance
Rating of Unitary Air-Conditioning &
Air-Source Heat Pump Equipment

ANSI/AHRI 340/360 (2007; Addendum 1 2010; Addendum 2 2011)
Performance Rating of Commercial and
Industrial Unitary Air-Conditioning and
Heat Pump Equipment

ANSI/AHRI 370 (2015; Addendum 1 2016) Sound Rating of
Large Outdoor Refrigerating and
Air-Conditioning Equipment

ANSI/AHRI 460 (2005) Performance Rating of Remote
Mechanical-Draft Air-Cooled Refrigerant
Condensers

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING
ENGINEERS (ASHRAE)

ANSI/ASHRAE 15 & 34 (2013) ANSI/ASHRAE Standard 15-Safety

Standard for Refrigeration Systems and
ANSI/ASHRAE Standard 34-Designation and
Safety Classification of Refrigerants

- ASHRAE 15 & 34 (2013) ASHRAE Standard 34-2016 Safety
Standard for Refrigeration Systems/ASHRAE
Standard 34-2016 Designation and Safety
Classification of Refrigerants-ASHRAE
Standard 34-2016
- ASHRAE 52.2 (2012) Method of Testing General
Ventilation Air-Cleaning Devices for
Removal Efficiency by Particle Size
- ASHRAE 55 (2017) Thermal Environmental Conditions
for Human Occupancy
- ASHRAE 62.1 (2016) Ventilation for Acceptable Indoor
Air Quality
- ASHRAE 90.1 - IP (2019) Energy Standard for Buildings
Except Low-Rise Residential Buildings

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

- ASME BPVC SEC IX (2017; Errata 2018) BPVC Section
IX-Welding, Brazing and Fusing
Qualifications
- ASME BPVC SEC VIII D1 (2019) BPVC Section VIII-Rules for
Construction of Pressure Vessels Division 1

AMERICAN WELDING SOCIETY (AWS)

- AWS Z49.1 (2021) Safety in Welding and Cutting and
Allied Processes

ASTM INTERNATIONAL (ASTM)

- ASTM B117 (2019) Standard Practice for Operating
Salt Spray (Fog) Apparatus
- ASTM C1071 (2019) Standard Specification for Fibrous
Glass Duct Lining Insulation (Thermal and
Sound Absorbing Material)
- ASTM D520 (2000; R 2011) Zinc Dust Pigment
- ASTM E84 (2023) Standard Test Method for Surface
Burning Characteristics of Building
Materials
- ASTM E2129 (2018) Standard Practice for Data
Collection for Sustainability Assessment
of Building Products

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

- NEMA ICS 6 (1993; R 2016) Industrial Control and

Systems: Enclosures

NEMA MG 1	(2021) Motors and Generators
NEMA MG 2	(2014) Safety Standard for Construction and Guide for Selection, Installation and Use of Electric Motors and Generators
NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)	
NFPA 54	(2024) National Fuel Gas Code
NFPA 70	(2023; ERTA 7 2023; TIA 23-15) National Electrical Code
U.S. DEPARTMENT OF DEFENSE (DOD)	
MIL-DTL-5541	(2006; Rev F) Chemical Conversion Coatings on Aluminum and Aluminum Alloys
UNDERWRITERS LABORATORIES (UL)	
UL 586	(2009; Reprint Sep 2022) UL Standard for Safety High-Efficiency Particulate, Air Filter Units
UL 900	(2015; Reprint Aug 2022) UL Standard for Safety Standard for Air Filter Units
UL 1995	(2015; Reprint Aug 2022) UL Standard for Safety Heating and Cooling Equipment

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Spare Parts

Posted Instructions

Coil Corrosion Protection

System Performance Tests

Training; G

Inventory

Environmental Data

Supplied Products

Manufacturer's Standard Catalog Data

SD-06 Test Reports

Refrigerant Tests, Charging, and Start-Up; G

System Performance Tests; G

SD-07 Certificates

Service Organizations

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G

SD-11 Closeout Submittals

Ozone Depleting Substances; S

1.4 QUALITY ASSURANCE

Carefully investigate the plumbing, fire protection, electrical, structural and finish conditions that would affect the work to be performed and arrange such work accordingly, furnishing required offsets, fittings, and accessories to meet such conditions. Submit drawings consisting of:

- a. Equipment layouts which identify assembly and installation details.
- b. Plans and elevations which identify clearances required for maintenance and operation.
- c. Wiring diagrams which identify each component individually and interconnected or interlocked relationships between components.
- d. Foundation drawings, bolt-setting information, and foundation bolts prior to concrete foundation construction for equipment indicated or required to have concrete foundations.
- e. Details, if piping and equipment are to be supported other than as indicated, which include loadings and type of frames, brackets, stanchions, or other supports.
- f. Automatic temperature control diagrams and control sequences.
- g. Installation details which includes the amount of factory set superheat and corresponding refrigerant pressure/temperature.
- h. Equipment schedules

1.5 DELIVERY, STORAGE, AND HANDLING

Protect stored items from the weather, humidity and temperature variations, dirt and dust, or other contaminants. Properly protect and care for all material both before and during installation. Submit an inventory of all the stored items. Replace any materials found to be damaged, at no additional cost to the Government. During installation, cap piping and similar openings capped to keep out dirt and other foreign

matter.

1.6 ENVIRONMENTAL REQUIREMENTS

For proper Indoor Environmental Quality, maintain pressure within the building as indicated. Ventilation must meet or exceed ASHRAE 62.1 and all published addenda. Meet or exceed filter media efficiency as tested in accordance with ASHRAE 52.2. Thermal comfort must meet or exceed ASHRAE 55 .

1.7 WARRANTY

Provide equipment with the Manufacturer's Standard Warranty.

PART 2 PRODUCTS

2.1 ENERGY EFFICIENCY REQUIREMENTS

42 USC 8259b requires the procurement of energy efficient products in product categories covered by the Energy Star program or the Federal Energy Management Program for designated products. A list of covered product categories is available from the Federal Energy Management Web site at <http://energy.gov/eere/femp/covered-product-categories>.

Submit Material, Equipment, and Fixtures List of all supplied products within a covered product category, including manufacturer's catalog numbers, specification and drawing reference number, warranty information, fabrication site, and energy performance data. For product categories covered by the Federal Energy Management Program, submit documentation that the product meets or exceeds FEMP-designated efficiency requirements.

2.2 MATERIALS

Provide Manufacturer's standard catalog data, at least 5 weeks prior to the purchase or installation of a particular component, highlighted to show material, size, options, performance charts and curves, etc. in adequate detail to demonstrate compliance with contract requirements. Data includes manufacturer's recommended installation instructions and procedures. If vibration isolation is specified for a unit, include vibration isolator literature containing catalog cuts and certification that the isolation characteristics of the isolators provided meet the manufacturer's recommendations. Submit data for each specified component. Minimum efficiency requirements must be in accordance with ASHRAE 90.1 - IP.

2.2.1 Standard Products

Provide materials and equipment that are standard products of a manufacturer regularly engaged in the manufacturing of such products, which are of a similar material, design and workmanship. The standard products must have been in satisfactory commercial or industrial use for 2 years prior to bid opening . The 2 year use includes applications of equipment and materials under similar circumstances and of similar size. The 2 years' experience must be satisfactorily completed by a product which has been sold or is offered for sale on the commercial market through advertisements, manufacturer's catalogs, or brochures. Products having less than a 2 year field service record will be acceptable if a certified record of satisfactory field operation, for not less than 6000

hours exclusive of the manufacturer's factory tests, can be shown. Products must be supported by a service organization. Ensure system components are environmentally suitable for the indicated geographic locations.

2.2.2 Product Sustainability Criteria

2.2.2.1 Energy Efficient Equipment

Provide equipment meeting the efficiency requirements as stated within this section and provide documentation in conformance with Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING paragraph ENERGY EFFICIENT EQUIPMENT.

2.2.2.2 Electrical Equipment / Motors

Provide electrical equipment, motors, motor efficiencies, and wiring which are in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Electrical motor driven equipment specified must be provided complete with motors, motor starters, and controls. Electrical characteristics must be as shown, and unless otherwise indicated, all motors of 1 horsepower and above with open, dripproof, totally enclosed, or explosion proof fan cooled enclosures, must be the premium efficiency type in accordance with NEMA MG 1. Field wiring must be in accordance with manufacturer's instructions. Each motor must conform to NEMA MG 1 and NEMA MG 2 and be of sufficient size to drive the equipment at the specified capacity without exceeding the nameplate rating of the motor. Motors must be continuous duty with the enclosure specified. Motor starters must be provided complete with thermal overload protection and other appurtenances necessary for the motor control indicated. Motors must be furnished with a magnetic across-the-line or reduced voltage type starter as required by the manufacturer. Motor duty requirements must allow for maximum frequency start-stop operation and minimum encountered interval between start and stop. Motors must be sized for the applicable loads. Motor torque must be capable of accelerating the connected load within 20 seconds with 80 percent of the rated voltage maintained at motor terminals during one starting period. Motor bearings must be fitted with grease supply fittings and grease relief to outside of enclosure. Manual or automatic control and protective or signal devices required for the operation specified and any control wiring required for controls and devices specified, but not shown, must be provided.

2.2.2.3 Ozone Depleting Substances

Unitary air conditioning equipment must not use CFC-based refrigerants. Refrigerant may be an approved alternative refrigerant in accordance with EPA's Significant New Alternative Policy (SNAP) listing. Provide documentation in conformance with Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING paragraph OZONE DEPLETING SUBSTANCES.

2.2.2.4 Local/Regional Materials

Use materials or products extracted, harvested, or recovered, as well as manufactured, within a 500 mile radius from the project site, if available from a minimum of three sources.

2.2.2.5 Environmental Data

Submit Table 1 of ASTM E2129 for the following products: .

2.2.3 Nameplates

Major equipment including compressors, condensers, receivers, heat exchanges, fans, and motors must have the manufacturer's name, address, type or style, model or serial number, and catalog number on a plate secured to the item of equipment. Plates must be durable and legible throughout equipment life and made of anodized aluminum. Fix plates in prominent locations with nonferrous screws or bolts.

2.2.4 Safety Devices

Exposed moving parts, parts that produce high operating temperature, parts which may be electrically energized, and parts that may be a hazard to operating personnel must be insulated, fully enclosed, guarded, or fitted with other types of safety devices. Safety devices must be installed so that proper operation of equipment is not impaired. Welding and cutting safety requirements must be in accordance with AWS Z49.1.

2.3 EQUIPMENT

2.3.1 Self-Contained Air Conditioners

2.3.1.1 Small-Capacity Self-Contained air conditioners (Not exceeding 65,000 Btu/h)

2.3.1.1.1 General

Unit must be an air-cooled, factory assembled, weatherproof packaged unit as indicated. Unit must be the air conditioning type conforming to applicable Underwriters Laboratories (UL) standards including UL 1995. Unit must be rated in accordance with ANSI/AHRI 340/360. Unit must be provided with equipment as specified in paragraph UNITARY EQUIPMENT COMPONENTS. Evaporator or supply fans must be direct drive forward curved centrifugal scroll type. Condenser fans must be manufacturer's standard for the unit specified and may be either propeller or centrifugal scroll type. Unit must be provided with a full factory operating charge of refrigerant. Unit must have an Energy Star label. Air Conditioners must have a minimum seasonal energy efficiency ratio (SEER) of 14, and

2.3.1.1.2 Air-to-Refrigerant Coils

Air-to-refrigerant coils must have seamless copper tubes of 5/16 inch minimum diameter with aluminum fins that are mechanically bonded or soldered to the tubes. Casing must be galvanized steel or aluminum. Contact of dissimilar metals must be avoided. Coils must be tested in accordance with ANSI/ASHRAE 15 & 34 at the factory and be suitable for the working pressure of the installed system. Each coil must be factory pressure and leak tested. Separate expansion devices must be provided for each compressor circuit.

2.3.1.1.3 Fan Section

Fan must be the centrifugal type in accordance with paragraph FANS. Do not locate fan and fan motor in the discharge airstream of the unit. Motors must have splash proof enclosure and be suitable for the indicated service. The unit design must prevent water from entering into the fan

section.

2.3.1.1.4 Compressor

Provide direct drive, variable speed type Compressor. Compressor must have internal over current and over temperature protection, internal pressure relief, rotor lock suction and discharge refrigerant connections, centrifugal oil pump, vibration isolation, and discharge refrigerant connections.

2.3.1.1.5 Refrigeration Circuit

Refrigerant containing components must comply with ANSI/ASHRAE 15 & 34 and be factory tested, cleaned, dehydrated, charged, and sealed. Refrigerant lines must have service pressure tap ports and refrigerant line filter.

2.3.1.1.6 Unit Controls

Provide units internally prewired by manufacturer with a 24 volt control circuit powered by an internal transformer. Terminal blocks must be provided for power wiring and external control wiring. Unit must be internally protected by fuses or a circuit breaker in accordance with UL 1995.

- a. Unit must be provided with microprocessor controls to provide all 24V control functions. Unit must be controlled by a two stage heating /cooling thermostat with automatic changeover. Unit must be controlled by a programmable electronic thermostat with heating setback and cooling setup with 7-day programming capability.
- b. Controls must include a control system interface to a BACnet Control system. The control system interface must meet DDC Hardware requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

2.3.1.1.7 Roof Curb

Provide a roof curb that mates with the unit to provide support and be completely weather tight. Provide curb with sealing strips to ensure an airtight seal between supply and return openings of the curb and unit. Design curb to allow ductwork to be directly connected to the curb. The roof curb must be provided by the Manufacturer of the equipment.

2.3.1.1.8 Primary/Supplemental Heat

Provide heating unit with internal thermal insulation having a fire hazard rating not to exceed 25 for flame spread and 50 for smoke developed as determined by ASTM E84.

2.3.1.1.8.1 Gas-Fired Heating Section

Provide factory assembled heating section as an integral part of the packaged unit. Design must be UL certified for outdoor application. Unit must have threaded gas connection. Provide heating section with an electronic ignition system to light burner each time thermostat calls for heat. A flame sensor must prove flame and keep main burner on. The main valve must close should a loss of flame occur. When the thermostat is satisfied, extinguish the main burner. Provide a forced combustion blower to supply combustion air to the heating section. Construct the heat

exchanger and burners of stainless steel.

2.3.1.1.9 Single Source Power Entry

Provide single source power entry to allow single source power connection to unit and heater combination. Single source power entry kit includes specific matching heater(s), high voltage terminal blocks, fuse blocks and fuses, cut-to-length interconnecting wiring, and junction box (if required) to provide power sources with fuse protection as required for both the unit and accessory heater. The equipment disconnect must be provided by the Manufacturer of the equipment.

2.3.1.1.10 Fully Modulating Economizer

Provide a fully modulating economizer with 0-100 percent fresh air damper, damper drive motor, and fixed dry bulb enthalpy control solid state enthalpy control. Control economizer operations by the pre-set position of the enthalpy control. Include a barometric relief damper with the down flow economizer to provide a pressure operated damper that is gravity closing and prohibits entrance of outside air on equipment "off" cycle.

Use water economizer in lieu of air economizers where possible. Where air economizers are used, provide separate dampers for ventilation air and minimum outdoor air requirements. Air economizers must not be used in ASHRAE climate zones 1, 2, 3a, and 4a.

2.3.1.1.11 Manual Outside Air Damper

Provide manual outside air damper with rain hood and screen suitable for up to 25 percent outside air. Dampers must have a maximum leakage rate of 3 CFM/ft² at 1 inch w.g. static pressure

2.3.1.1.12 Low Ambient Control

Provide low ambient control to allow cycling of compressor for cooling operation at low ambient temperatures down to 0 degrees F.

2.3.1.1.13 Filters

Provide a 1 inch MERV 8, throwaway filter.

2.3.1.2 Large-Capacity Self-Contained air conditioners (Greater than 65,000 Btu/h)

2.3.1.2.1 General

Provide an air-cooled, factory assembled, weatherproof packaged unit for horizontal airflow. Exterior panels must be zinc coated galvanized steel phosphatized and painted. All access doors and panels must be hinged with neoprene gaskets. Unit must be listed, labeled, and classified in accordance with UL 1995. Unit must be rated in accordance with ANSI/AHRI 340/360. Provide unit with equipment as specified in paragraph UNITARY EQUIPMENT COMPONENTS. Evaporator or supply fans must be direct drive forward curved centrifugal scroll type. Condenser fans must be manufacturer's standard for the unit specified and may be propeller type. UProvide unit with a full factory operating charge of refrigerant. Unit must be 100 percent run tested at the factory. No penetrations are allowed within the perimeter of the curb in the down flow unit's base pan other than the raised 1-1/8 inch high supply/return openings to provide

added water integrity precaution from condensate drain back up.

Provide a belt driven, forward curved centrifugal indoor fan with adjustable motor sheaves. Thermally protect all motors. Provide unit with a removable, reversible, double-sloped condensate drain pan. Air conditioners must have a minimum seasonal energy efficiency ratio (SEER) of 14, and

2.3.1.2.2 Casing

Construct exterior casings for the specified unitary equipment of factory phosphatized and painted galvanized steel or aluminum sheet metal and galvanized or aluminum structural members. Fit casing with lifting provisions, access panels or doors, fan vibration isolators, electrical control panel, corrosion-resistant components, structural support members, insulated condensate drip pan and drain, and internal insulation in the cold section of the casing. All access doors and panels must have neoprene gaskets. Casing must have double-wall, hinged access doors for filters, heating, return/exhaust air, and supply fan section. Incorporate provisions to permit replacement of major unit components. Seal penetrations of cabinet surfaces, including the floor. Unit base must be watertight. Fit unit with a drain pan which extends under all areas where water may accumulate. Fabricate drain pan from Type 30X stainless steel, galvanized steel with protective coating, or an approved plastic material. Pan insulation must be water impervious. Extent and effectiveness of the insulation of unit air containment surfaces must prevent, within limits of the specified insulation, heat transfer between the unit exterior and ambient air, heat transfer between the two conditioned air streams, and condensation on surfaces. Insulation must conform to ASTM C1071.

2.3.1.2.3 Air-to-Refrigerant Coils

Provide air-to-refrigerant coils with seamless copper tubes of 5/16 inch minimum diameter with aluminum fins that are mechanically bonded or soldered to the tubes. Casing must be galvanized steel or aluminum. Avoid contact of dissimilar metals. Test coils in accordance with ANSI/ASHRAE 15 & 34 at the factory and must be suitable for the working pressure of the installed system. Factory pressure and leak test each coil.

- a. Provide separate expansion devices for each compressor circuit. Condensate drain pans must be removable and double-sloped.
- b. Dual compressor units must have intermingled evaporator coils.
- c. Condensate drain pans must be removable and double-sloped.
- d. Provide condenser coils with hail protection guards.

2.3.1.2.4 Compressor

Provide direct drive, scroll type compressor. Compressor must have internal over current and over temperature protection, internal pressure relief, high pressure cutout, rotor lock suction and discharge refrigerant connections, centrifugal oil pump, vibration isolation, and discharge refrigerant connections. Compressors must have crankcase heaters. Motor

must be suction gas-cooled. Cooling partial load capacity must be provided by a variable speed compressor.

2.3.1.2.5 Refrigeration Circuit

Refrigerant containing components must comply with ANSI/ASHRAE 15 & 34 and be factory tested, cleaned, dehydrated, charged, and sealed. Provide refrigerant lines with service pressure tap ports and refrigerant line filter.

2.3.1.2.6 Unit Controls

Provide units internally prewired by manufacturer with a 24 volt electromechanical control circuit powered by an internal transformer. Provide terminal blocks for power wiring and external control wiring. Internally protect unit by fuses or a circuit breaker in accordance with UL 1995. Units with three-phase power must be equipped with phase monitoring protection to protect against problems caused by phase loss, phase imbalance and phase reversal.

- a. Provide unit with microprocessor controls to provide all 24V control functions. Control unit by a two stage heating /cooling thermostat with automatic changeover. Control unit by a programmable electronic thermostat with heating setback and cooling setup with 7-day programming capability.
- b. Controls must include a control system interface to a BACnet Control system. The control system interface must meet DDC Hardware requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

2.3.1.2.7 Supply Air Fan

Units having AHRI cooling capacity equal or greater than 110,000 Btu/h must have supply fans controlled by variable speed motors.

Provide supply air plenum fan with backward-curved fan wheel.

2.3.1.2.8 Roof Curb

Provide a roof curb that mates with the unit to provide support and be completely weather tight. Provide curb with sealing strips to ensure an airtight seal between supply and return openings of the curb and unit. Design curb to allow ductwork to be directly connected to the curb. The roof curb must be provided by the Manufacturer of the equipment.

2.3.1.2.9 Primary/Supplemental Heat

Provide heating unit with internal thermal insulation having a fire hazard rating not to exceed 25 for flame spread and 50 for smoke developed as determined by ASTM E84.

2.3.1.2.9.1 Gas-Fired Heating Section

Construct gas-fired heat exchanger and burner of stainless steel suitable for natural gas fuel supply. Provide burner with direct spark ignition. Heating section must have modulation with a turn down ratio of at least 4 to 1. Provide heating section completely assembled and integral to unit. Fire test all units prior to shipment. Valve must include a pressure

regulator. Supply combustion air with a centrifugal combustion air blower with built-in thermal over load protection. Safety controls must include a flame sensor and air pressure switch. Mount heater section to eliminate noise from expansion and contraction and completely accessible for service. Gas equipment must bear the AGA label for the type of service involved. Provide burner in accordance with NFPA 54.

2.3.1.2.10 Single Source Power Entry

Provide single source power entry to allow single source power connection to unit and heater combination. Single source power entry kit includes specific matching heater(s), high voltage terminal blocks, fuse blocks and fuses, cut-to-length interconnecting wiring, and junction box (if required) to provide power sources with fuse protection as required for both the unit and accessory heater. The equipment disconnect must be provided by the Manufacturer of the equipment.

2.3.1.2.11 Fully Modulating Economizer

Provide fully modulating economizer to include 0-100 percent fresh air damper, damper drive motor, and differential enthalpy control. Control economizer operations by the pre-set position of the enthalpy control. Include a barometric relief damper with the down flow economizer to provide a pressure operated damper that is gravity closing and prohibits entrance of outside air on equipment "off" cycle. Economizer dampers must be ultra low-leak type with leakage rate of one percent based on testing data completed in accordance with AMCA 500-D.

2.3.1.2.12 Manual Outside Air Damper

Provide manual outside air damper with rain hood and screen suitable for up to 25 percent outside air. Test Louvers in accordance with AMCA 500-L.

2.3.1.2.13 Low Ambient Control

Provide low ambient control to allow cycling of compressor for cooling operation at low ambient temperatures down to 0 degrees F.

2.3.1.2.14 Filters

Provide 2 inch thick high efficiency throwaway type filters that are MERV 8. Filters must have an average dust spot efficiency of 25-35 percent and an average arrestance of 90 percent when tested in accordance with ASHRAE 52.2. Filters must be UL Class 1.

2.3.2 Mini-Split-System Air Conditioners Heat Pumps

2.3.2.1 Small-Capacity Split-System Air-Conditioners (Not Exceeding 65,000 Btu/hr)

Provide an air-cooled, split system which employs a remote condensing unit, a separate wall mounted indoor unit, and interconnecting refrigerant piping. Provide the heat pump type unit conforming to applicable Underwriters Laboratories (UL) standards including UL 1995. Unit must be rated in accordance with ANSI/AHRI 210/240. Provide indoor unit with necessary fans, air filters, and galvanized steel cabinet construction. The remote unit must be as specified in paragraph CONDENSING UNIT. Provide double-width, double inlet, forward curved backward inclined, or airfoil blade, centrifugal scroll type evaporator or supply fans. Provide

the manufacturer's standard condenser or outdoor fans for the unit specified and may be either propeller or centrifugal scroll type. Fan and condenser motors must have drip proof enclosures. Design unit to operate at outdoor ambient temperatures up to 115 degrees F.

2.3.2.1.1 Energy Efficiency

Provide unit with an Energy Star label. Air Conditioners must have a minimum seasonal energy efficiency ratio (SEER) of 14, and

2.3.2.1.2 Air-to-Refrigerant Coil

Provide condensing coils with copper tubes of 3/8 inch minimum diameter with aluminum fins that are mechanically bonded or soldered to the tubes. Casing must be galvanized steel. Avoid contact of dissimilar metals. Test coils in accordance with ASHRAE 15 & 34 at the factory and ensure suitability for the working pressure of the installed system. Dehydrate and seal each coil testing and prior to evaluation and charging.

Coat condenser coil with a uniformly applied type coating to all coil surface areas without material bridging between fins. Apply coating at either the coil or coating manufacturer's factory. Coating process must ensure complete coil encapsulation and be capable of withstanding a minimum 500 hours exposure to the salt spray test specified in ASTM B117 using a 5 percent sodium chloride solution.

2.3.2.1.3 Compressor

Provide direct drive scroll type compressor. Provide compressor with internal over temperature and pressure protector; sump heater; oil pump; high pressure and low pressure controls; and liquid line dryer.

2.3.2.1.4 Refrigeration Circuit

Refrigerant-containing components must comply with ASHRAE 15 & 34 and be factory tested, cleaned, dehydrated, charged, and sealed. Provide each unit with a factory operating charge of refrigerant and oil or a holding charge. Field charge unit shipped with a holding charge. Provide refrigerant charging valves. Provide filter-drier in liquid line to prevent freeze-up in event of loss of water flow during heating cycle.

2.3.2.1.5 Unit Controls

Provide unit internally prewired with a 24 volt control circuit powered by an internal transformer. Provide terminal blocks for power wiring and external control wiring. Internally protect unit by fuses or a circuit breaker in accordance with UL 1995. Equip units with three-phase power with phase monitoring protection to protect against problems caused by phase loss, phase imbalance and phase reversal. Provide unit with microprocessor controls to provide all 24V control functions.

Controls must include a control system interface to a BACnet Control system. The control system interface, as well as any network between physically separate units, must meet the requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

Communication networks between physically separate units in a split system must be in accordance with either Section 23 09 23.02 BACNET DIRECT

DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS or Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS. and must match the protocol used by the control system interface.

2.3.2.1.6 Condensing Coil

Provide coils with copper tubes of 3/8 inch minimum diameter with aluminum fins that are mechanically bonded or soldered to the tubes. Provide galvanized steel or aluminum casing. Avoid contact of dissimilar metals. Test coils in accordance with ANSI/ASHRAE 15 & 34 at the factory and ensure suitability for the working pressure of the installed system. Dehydrate and seal each coil after testing and prior to evaluation and charging. Provide separate expansion devices for each compressor circuit.

2.3.2.1.7 Remote Condenser or Condensing Unit

Fit each remote condenser coil fitted with a manual isolation valve and an access valve on the coil side. Saturated refrigerant condensing temperature must not exceed 120 degrees F at 104 degrees F ambient. Provide unit with low ambient condenser controls to ensure proper operation in an ambient temperature of 20degrees F. Provide fan and cabinet construction as specified in paragraph UNITARY EQUIPMENT ACCESSORIES. Fan and condenser motors must have drip proof enclosures. Condensing unit must have controls to initiate a refrigerant pump down cycle at system shut down on each refrigerant circuit.

2.3.2.1.7.1 Air-Cooled Condenser

Provide Unit in accordance with ANSI/AHRI 460 and conform to the requirements of UL 1995. Provide factory fabricated, tested, packaged, and self-contained unit; complete with casing, propeller type fans, heat rejection coils, connecting piping and wiring, and all necessary accessories.

2.3.2.1.8 Primary/Supplemental Heat

Provide heating unit with internal thermal insulation having a fire hazard rating not to exceed 25 for flame spread and 50 for smoke developed as determined by ASTM E84.

2.3.2.1.8.1 Gas-Fired Heating Section

Construct the gas-fired heat exchanger and burner of stainless steel suitable for natural gas fuel supply. Burner must have direct spark . Heating section must be completely assembled and integral to unit, having modulation with a turn down ratio of at least 4 to 1. Fire test all units prior to shipment. Valve must include a pressure regulator. Supply combustion air with a centrifugal combustion air blower with built-in thermal over load protection. Safety controls must include a flame sensor and air pressure switch. Mount heater section to eliminate noise from expansion and contraction, and allow accessibility for service. Gas equipment must bear the AGA label for the type of service involved. Provide burner in accordance with NFPA 54.

2.3.2.1.9 Air Filters

Provide filters of the sectional or panel type that are capable of filtering the entire air supply. Mount filter(s) integral within the unit and make accessible by hinged access panel(s). 1 inch MERV 7, provide

throwaway filter on all units below 6 Tons.

Provide filter rack that can be converted to 2.0 inch capability. Filters must have an average dust spot efficiency of 25-35 percent and an average arrestance of 90 percent when tested in accordance with ASHRAE 52.2. Provide UL Class 1 filters.

2.3.2.1.10 Fans

Provide direct driven, statically and dynamically balanced, centrifugal or propeller type fans. Design the outdoor fan so that condensate will evaporate without drip, splash, or spray on building exterior. Provide indoor fan with a minimum two-speed motor with built-in overload protection. Fan motors must be the inherently protected, permanent split-capacitor type.

2.3.2.2 Large-Capacity Split-System Air Conditioners (Greater Than 65,000 Btu/h)

Provide an air-cooled, split system which employs a remote condensing unit, a separate floor mounted indoor unit, and interconnecting refrigerant piping. Provide the air conditioning type unit conforming to applicable Underwriters Laboratories (UL) standards including UL 1995. Unit must be rated in accordance with ANSI/AHRI 210/240. Provide unit with necessary fans, air filters, and cabinet construction as specified in paragraph UNITARY EQUIPMENT ACCESSORIES. Provide double-width, double inlet, forward curved centrifugal scroll type evaporator or supply fans. Provide the manufacturer's standard for the unit specified and may be propeller type condenser or outdoor fans. Enclose fan condenser motors in drip proof enclosures and permanently lubricate ball bearings. Air Conditioners must have a minimum seasonal energy efficiency ratio (SEER) of 14, and

2.3.2.2.1 Air-To-Refrigerant Coil

Provide coils with copper tubes of 3/8 inch minimum diameter with aluminum fins that are mechanically bonded or soldered to the tubes. Provide casing of galvanized steel. Avoid contact of dissimilar metals. Test coils in accordance with ASHRAE 15 & 34 at the factory and ensure suitability for the working pressure of the installed system. Dehydrate and seal each coil testing and prior to evaluation and charging. Provide each unit with a factory operating charge of refrigerant and oil. Field charge unit shipped with a holding charge with refrigerant and oil. Provide separate expansion devices for each compressor circuit. Condenser coil must have an integral sub-cooler.

2.3.2.2.2 Compressor

Provide direct drive, semi-hermetic or hermetic reciprocating, or scroll type compressor capable of operating at partial load conditions. Compressor must be capable of continuous operation down to the lowest step of unloading as specified. Equip compressors of 10 tons and larger with capacity reduction devices to produce automatic capacity reduction of at least 50 percent. If standard with the manufacturer, two or more compressors may be used in lieu of a single compressor with unloading capabilities, in which case the compressors operate in sequence, and each compressor has an independent refrigeration circuit through the condenser

and evaporator. Start compressors in the unloaded position. Provide each compressor with vibration isolators, crankcase heater, thermal overloads, high and low pressure safety cutoffs and protection against short cycling.

2.3.2.2.3 Refrigeration Circuit

Refrigerant-containing components must comply with ASHRAE 15 & 34 and be factory tested, cleaned, dehydrated, charged, and sealed. Provide refrigerant charging valves and connections, and pumpdown valves for each circuit. Provide reversible-flow type filter-drier in each liquid line. Refrigerant flow control devices must be an adjustable superheat thermostatic expansion valve with external equalizer matched to coil, capillary or thermostatic control, and a pilot solenoid controlled, leak-tight, four-way refrigerant flow reversing valve. Provide a refrigerant suction line thermostatic control to prevent freeze-up in event of loss of water flow during heating cycle.

2.3.2.2.4 Primary/Supplemental Heat

Provide heating unit with internal thermal insulation having a fire hazard rating not to exceed 25 for flame spread and 50 for smoke developed as determined by ASTM E84.

2.3.2.2.4.1 Gas-Fired Heating Section

Construct the gas-fired heat exchanger and burner of stainless steel suitable for natural gas fuel supply. Burner must have direct spark. Heating section must be completely assembled and integral to unit, having modulation with a turn down ratio of at least 4 to 1. Fire test all units prior to shipment. Valve must include a pressure regulator. Supply combustion air with a centrifugal combustion air blower with built-in thermal over load protection. Safety controls must include a flame sensor and air pressure switch. Mount heater section to eliminate noise from expansion and contraction, and allow accessibility for service. Gas equipment must bear the AGA label for the type of service involved. Provide burner in accordance with NFPA 54.

2.3.2.2.5 Unit Controls

Provide unit internally prewired with a 24 volt control circuit powered by an internal transformer. Provide terminal blocks for power wiring and external control wiring. Unit must have cutoffs for high pressure, and low oil pressure for compressors with positive displacement oil pumps, supply fan failure, and safety interlocks on all service panels. Head pressure controls must sustain unit operation with ambient temperature of 20degrees F. Adjustable-cycle timers must prevent short-cycling. Stage multiple compressors by means of a time delay. Internally protect unit by a circuit breaker in accordance with UL 1995. Make low cost cooling possible by means of a control circuit which will modulate dampers to provide 100 percent outside air while locking out compressors.

Controls must include a control system interface to a BACnet Control system. The control system interface, as well as any network between physically separate units, must meet the requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

Communication networks between physically separate units in a split system must be in accordance with either Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS or Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS. and must match the protocol used by the control system interface.

2.3.2.2.6 Remote Condenser or Condensing Unit

Units with capacities 135,000 Btuh or greater must produce a maximum AHRI sound rating of 85 dB when rated in accordance with ANSI/AHRI 370. Fit each remote condenser coil with a manual isolation valve and an access valve on the coil side. Saturated refrigerant condensing temperature must not exceed 120 degrees F at 95 degrees F ambient. Provide unit with low ambient condenser controls to ensure proper operation in an ambient temperature of 20 degrees F. Provide fan and cabinet construction must be provided as specified in paragraph UNITARY EQUIPMENT COMPONENTS. Fan and condenser motors must have dripproof enclosures. Condensing unit must have controls to initiate a refrigerant pump down cycle at system shut down on each refrigerant circuit.

2.3.2.2.6.1 Air-Cooled Condenser

Provide unit rated in accordance with ANSI/AHRI 460 and conform to the requirements of UL 1995. Provide factory fabricated, tested, packaged, and self-contained unit. Unit must be complete with casing, propeller or centrifugal type fans, heat rejection coils, connecting piping and wiring, and all necessary appurtenances.

- a. Provide interconnecting refrigeration piping, electrical power, and control wiring between the condensing unit and the indoor unit as required and as indicated. Provide electrical and refrigeration piping terminal connections between condensing unit and evaporator units.
- b. Low ambient control for multi-circuited units serving more than one evaporator coil must provide independent condenser pressure controls for each refrigerant circuit. Set controls to produce a minimum of 95 degrees F saturated refrigerant condensing temperature. Provide unit with a liquid subcooling circuit that ensures proper liquid refrigerant flow to the expansion device over the specified application range of the condenser. Unit must be provided with manufacturer's standard liquid subcooling. Liquid seal the subcooling circuit.
- c. Coils must have copper or aluminum tubes of 3/8 inch minimum diameter with copper or aluminum fins that are mechanically bonded or soldered to the tubes. Casing must be galvanized steel or aluminum. Avoid contact of dissimilar metals. Test coils in accordance with ASHRAE 15 & 34 at the factory and ensure suitability for the working pressure of the installed system. Dehydrate and seal each coil after testing and prior to evaluation and charging. Provide each unit with a factory operating charge of refrigerant and oil or a holding charge. Field charge unit shipped with a holding charge. Provide separate expansion devices for each compressor circuit.
- d. Provide a complete control system with required accessories for regulating condenser pressure by fan cycling, solid-state variable fan

speed, modulating condenser coil or fan dampers, flooding the condenser, or a combination of the above. Construct unit mounted control panels or enclosures in accordance with applicable requirements of NFPA 70 and house in NEMA ICS 6, Class 1 or 3A enclosures. Controls must include control transformer, overload protective devices, interface with local and remote components, and intercomponent wiring to terminal block points.

2.3.2.2.6.2 Compressor

Provide compressor rated in accordance with AHRI 540. Provide direct drive, semi-hermetic or hermetic reciprocating, or scroll type compressor capable of operating at partial load conditions. Compressor must be capable of continuous operation down to the lowest step of unloading as specified. Provide units 120,000 Btuh and larger with capacity reduction devices to produce automatic capacity reduction of at least 50 percent. If standard with the manufacturer, two or more compressors may be used in lieu of a single compressor with unloading capabilities, in which case the compressors operate in sequence, and each compressor must have an independent refrigeration circuit through the condenser and evaporator. Each compressor must start in the unloaded position. Provide each compressor with vibration isolators, crankcase heater, thermal overloads, and high and low pressure safety cutoffs and protection against short cycling.

2.3.2.2.6.3 Fans

Provide fan wheel shafts supported by either maintenance-accessible grease lubricated antifriction block-type bearings, or permanently lubricated ball bearings. Mount fan motor and fan assembly on a common base to allow consistent belt tension with no relative motion between fan and motor shafts. The entire fan motor and fan assembly must be completely vibrationally isolated from the unit. Select unit fans to produce the cfm required at the fan total pressure. Motor starters, if applicable, must be magnetic across-the-line type with a open drip-proof enclosure. Provide manual type thermal overload protection. Construct fan wheels of aluminum or galvanized steel. Provide centrifugal fan wheel housings of galvanized steel, and construct centrifugal fan casings of aluminum or galvanized steel. Steel elements of fans, except fan shafts, must be fabricated of mill galvanized steel. Recoat mill-galvanized steel surfaces and edges damaged or cut during fabrication by forming, punching, drilling, welding, or cutting with an approved zinc-rich compound. Statically and dynamically balance fan wheels or propellers. Provide double inlet forward-curved type fan wheels. Fan must reach rated rpm before the fan shaft passes through the first critical speed. Fans must be belt-driven with adjustable sheaves. Select the sheave size so that the fan speed at the approximate midpoint of the sheave adjustment produces the specified air quantity. Provide centrifugal scroll-type fans with streamlined orifice inlet and V-belt drive. Each drive must be independent of any other drive. Condenser fans must be propeller type, direct drive, statically balanced with galvanized steel blades and permanently lubricated ball bearings. Protect condenser fan motor drive bearings with water slingers or shields. Fit all belt drives with guards where exposed to contact by personnel.

2.3.2.2.7 Filters

Provide filters of the sectional or panel type, capable of filtering the entire air supply. Mount filter(s) integral within the unit and make

accessible by hinged access panel(s). Factory supply 2.0 inch, MERV 8, throwaway filters. Filters must have an average dust spot efficiency of 90-95 percent and an average arrestance of 90 percent when tested in accordance with ASHRAE 52.2. Provide UL Class 1 filters.

2.4 COMPONENTS

2.4.1 Refrigerant and Oil

Refrigerant must be one of the fluorocarbon gases. Refrigerants must have number designations and safety classifications in accordance with ASHRAE 15 & 34. Refrigerants must meet the requirements of AHRI 700 as a minimum. Provide a complete charge of refrigerant for the installed system as recommended by the manufacturer. Lubricating oil must be of a type and grade recommended by the manufacturer for each compressor. Where color leak indicator dye is incorporated, charge must be in accordance with manufacturer's recommendation.

2.4.2 Fans

Fan wheel shafts must be supported by either maintenance-accessible lubricated antifriction block-type bearings, or permanently lubricated ball bearings. Unit fans must be selected to produce the cfm required at the fan total pressure. Motor starters, if applicable, must be magnetic across-the-line type with a dripproof enclosure. Thermal overload protection must be of the manual or automatic-reset type. Fan wheels or propellers must be constructed of aluminum or galvanized steel. Centrifugal fan wheel housings must be of galvanized steel, and both centrifugal and propeller fan casings must be constructed of aluminum or galvanized steel. Steel elements of fans, except fan shafts, must be hot-dipped galvanized after fabrication or fabricated of mill galvanized steel. Mill-galvanized steel surfaces and edges damaged or cut during fabrication by forming, punching, drilling, welding, or cutting must be recoated with an approved zinc-rich compound. Fan wheels or propellers must be statically and dynamically balanced. Forward curved fan wheels must be limited to inches. Direct-drive fan motors must be of the multiple-speed variety. Belt-driven fans must have adjustable sheaves to provide not less than percent fan-speed adjustment. The sheave size must be selected so that the fan speed at the approximate midpoint of the sheave adjustment will produce the specified air quantity. Centrifugal scroll-type fans must be provided with streamlined orifice inlet and V-belt drive. Each drive will be independent of any other drive. Propeller fans must be direct-drive drive type with adjustable pitch blades. V-belt driven fans must be mounted on a corrosion protected drive shaft supported by either maintenance-accessible lubricated antifriction block-type bearings, or permanently lubricated ball bearings. Each drive will be independent of any other drive. Drive bearings must be protected with water slingers or shields. V-belt drives must be fitted with guards where exposed to contact by personnel and fixed pitch sheaves.

2.4.3 Primary/Supplemental Heating

2.4.3.1 Gas-Fired Heating Section

Gas-fired heat exchanger must be constructed of aluminized steel, ceramic coated cold-rolled steel or stainless steel suitable for natural gas fuel supply. Burner must have direct spark or hot surface ignition. Valve must include a pressure regulator. Combustion air must be supplied with a centrifugal combustion air blower. Safety controls must include a flame

sensor and air pressure switch. Heater section must be mounted to eliminate noise from expansion and contraction and must be completely accessible for service. Gas equipment must bear the AGA label for the type of service involved. Burner must be in accordance with NFPA 54.

2.4.4 Air Filters

Provide filters to filter outside air and return air and locate as indicated . Provide replaceable (throw-away) type. Filters must conform to UL 900, Class 1 . Polyurethane filters cannot be used on units with multiframe filters.

Air filters must be listed in accordance with requirements of UL 900, except high efficiency particulate air filters of 99.97 percent efficiency by the DOP Test Method must be as listed under the label service and must meet the requirements of UL 586.

2.4.4.1 Extended Surface Pleated Panel Filters

Filters must be 2 inch depth sectional type of the size indicated and must have an average efficiency of 25 to 30 percent when tested in accordance with ASHRAE 52.2. Initial resistance at 500 feet/minute must not exceed 0.36 inches water gauge. Filters must be UL Class 2. Media must be nonwoven cotton and synthetic fiber mat. A wire support grid bonded to the media must be attached to a moisture resistant fiberboard frame. Four edges of the filter media must be bonded to the inside of the frame to prevent air bypass and increase rigidity.

2.4.4.2 Replaceable Media Filters

Provide replaceable media filters of the dry-media type, of the size required to suit the application. Filtering media must not be less than 2 inches thick fibrous glass media pad supported by a structural wire grid or woven wire mesh. Pad must be enclosed in a holding frame of not less than 16 gauge galvanized steel, and equipped with quick-opening mechanism for changing filter media. Base the air flow capacity of the filter on net filter face velocity not exceeding 300 feet/minute, with initial resistance of 0.13 inches water gauge. Average efficiency must be not less than 5 percent when tested in accordance with ASHRAE 52.2.

2.4.4.3 Sectional Cleanable Filters

Provide sufficient oil to coat filters six times based on 1 pint of oil per each 10 square feet of filter area. Provide washing and charging tanks for cleaning and coating filters. Filters must have a MERV of 8 when tested in accordance with ASHRAE 52.2.

Cleanable filters must be 1 inches thick. Viscous adhesive must be provided in 5 gallon containers in sufficient quantity for 12 cleaning operations and not less than one quart for each filter section. One washing and charging tank must be provided for every 100 filter sections or fraction thereof. Each washing and charging unit must consist of a tank and double drain rack mounted on legs. Drain rack must be provided with dividers and partitions to properly support the filters in the draining position.

2.4.4.4 High Efficiency Filters

Filters must have a MERV of 17 when tested in accordance with ASHRAE 52.2.

Filter assembly must include; holding frame and fastener assembly, filter cartridge, mounting frame, and retainer assembly. Reinforce filter media with glass fiber mat. Pressure drop across clean filter exceeding 2.0 inches of water gage is not permitted. Precede high efficiency filters with a UL Class 2 replaceable type filter.

2.4.4.5 Manometers

Provide inclined-type manometers for filter stations of 2,000 cfm capacity or larger including filters furnished as integral parts of air-handling units and filters installed separately. Provide sufficient length to read at least one inch of water column with 10 major graduations, and equipped with spirit level. Equip manometers with overpressure safety traps to prevent loss of fluid, and two three-way vent valves for checking zero setting. Mercury cannot be used as the operating fluid.

2.4.5 Coil Frost Protection

Provide each circuit with a manufacturer's standard coil frost protection system. The coil frost protection system must use a temperature sensor in the suction line of the compressor to shut the compressor off when coil frosting occurs. Use timers to prevent the compressor from rapid cycling.

2.4.6 Internal Dampers

Dampers must be parallel blade type with renewable blade seals and be integral to the unitary unit. Damper provisions must be provided for each outside air intake, exhaust, economizer, and mixing boxes. Dampers must have minimum position stops and operate as specified.

2.4.7 Mixing Boxes

Mixing boxes must match the base unit in physical size and must include equally-sized flanged openings, each capable of full air flow. Arrangement must be as indicated.

2.4.8 Cabinet Construction

Casings for the specified unitary equipment must be constructed of galvanized steel or aluminum sheet metal and galvanized or aluminum structural members. Minimum thickness of single wall exterior surfaces must be 18 gauge galvanized steel or 0.071 inch thick aluminum on units with a capacity above 20 tons and 20 gauge galvanized steel or 0.064 inch thick aluminum on units with a capacity less than 20 tons. Casing must be fitted with lifting provisions, access panels or doors, fan vibration isolators, electrical control panel, corrosion-resistant components, structural support members, insulated condensate drip pan and drain, and internal insulation in the cold section of the casing. Where double-wall insulated construction is proposed, minimum exterior galvanized sheet metal thickness must be 20 gauge. Provisions to permit replacement of major unit components must be incorporated. Penetrations of cabinet surfaces, including the floor, must be sealed. Unit must be fitted with a drain pan which extends under all areas where water may accumulate. Drain pan must be fabricated from Type 300 stainless steel, galvanized steel with protective coating as required, or an approved plastic material. Pan insulation must be water impervious. Extent and effectiveness of the insulation of unit air containment surfaces must prevent, within limits of the specified insulation, heat transfer between the unit exterior and ambient air, heat transfer between the two conditioned air streams, and

condensation on surfaces. Insulation must conform to ASTM C1071. Paint and finishes must comply with the requirements specified in paragraph FACTORY COATING.

2.4.8.1 Indoor Cabinet

Indoor cabinets must be suitable for the specified indoor service and enclose all unit components.

2.4.8.2 Outdoor Cabinet

Outdoor cabinets must be suitable for outdoor service with a weathertight, insulated and corrosion-protected structure. Cabinets constructed exclusively for indoor service which have been modified for outdoor service are not acceptable.

2.4.9 Condenser Water Piping And Accessories

2.4.10 Refrigerant Piping

Provide refrigerant piping in accordance with Section 23 23 00 REFRIGERANT PIPING.

2.4.11 Condensate Drain Piping

2.4.12 Ductwork

Provide ductwork in accordance with Section 23 30 00 HVAC AIR DISTRIBUTION.

2.4.13 Temperature Controls

Provide temperature controls .

2.5 UNITARY EQUIPMENT ACCESSORIES AND MISCELLANEOUS EQUIPMENT

2.5.1 Air Economizer

Provide factory installed economizer with fully modulating 0-100 percent motor and dampers, barometric relief, minimum position setting and fixed dry bulb. Field install solid state enthalpy and differential enthalpy control.

2.6 FINISHES

2.6.1 Coil Corrosion Protection

Provide coil with a uniformly applied epoxy electrodeposition type coating to all coil surface areas without material bridging between fins. Submit product data on the type coating selected, the coating thickness, the application process used, the estimated heat transfer loss of the coil, and verification of conformance with the salt spray test requirement. Coating must be applied at either the coil or coating manufacturer's factory. Coating process must ensure complete coil encapsulation.

Coating must be capable of withstanding a minimum 1,000 hours exposure to the salt spray test specified in ASTM B117 using a 5 percent sodium chloride solution.

2.6.2 Equipment and Components Factory Coating

Unless otherwise specified, equipment and component items, when fabricated from ferrous metal, must be factory finished with the manufacturer's standard finish, except that items located outside of buildings must have weather resistant finishes that will withstand 125 hours exposure to the salt spray test specified in ASTM B117 using a 5 percent sodium chloride solution. Immediately after completion of the test, the specimen must show no signs of blistering, wrinkling, cracking, or loss of adhesion and no sign of rust creepage beyond 1/8 inch on either side of the scratch mark. Cut edges of galvanized surfaces where hot-dip galvanized sheet steel is used must be coated with a zinc-rich coating conforming to ASTM D520, Type I.

Where stipulated in equipment specifications of this section, coat finned tube coils of the affected equipment as specified below. Apply coating at the premises of a company specializing in such work. Degrease and prepare for coating in accordance with the coating applicator's procedures for the type of metals involved. Completed coating must show no evidence of softening, blistering, cracking, crazing, flaking, loss of adhesion, or "bridging" between the fins.

2.6.2.1 Phenolic Coating

Provide a resin base thermosetting phenolic coating. Apply coating by immersion dipping of the entire coil. Provide a minimum of two coats. Bake or heat dry coils following immersions. After final immersion and prior to final baking, spray entire coil with particular emphasis given to building up coating on sheared edges. Total dry film thickness must be 2.5 to 3.0 mils.

2.6.2.2 Chemical Conversion Coating with Polyelastomer Finish Coat

Dip coils in a chemical conversion solution to molecularly deposit a corrosion resistant coating by electrolysis action. Chemical conversion coatings must conform to MIL-DTL-5541, Class 1A. Cure conversion coating at a temperature of 110 to 140 degrees F for a minimum of 3 hours. Coat coil surfaces with a complex polymer primer with a dry film thickness of 1 mil. Cure primer coat for a minimum of 1 hour. Using dip tank method, provide three coats of a complex polyelastomer finish coat. After each of the first two finish coats, cure the coils for 1 hour. Following the third coat, spray a fog coat of an inert sealer on the coil surfaces. Total dry film thickness must be 2.5 to 3.0 mils. Cure finish coat for a minimum of 3 hours. Coating materials must have 300 percent flexibility, operate in temperatures of minus 50 to plus 220 degrees F, and protect against atmospheres of a pH range of 1 to 14.

2.6.2.3 Vinyl Coating

Apply coating using an airless fog nozzle. For each coat, make at least two passes with the nozzle. Materials to be applied are as follows:

- a. Total dry film thickness, 6.5 mils maximum
- b. Vinyl Primer, 24 percent solids by volume: One coat 2 mils thick

- c. Vinyl Copolymer, 30 percent solids by volume: One coat 4.5 mils thick

2.6.3 Factory Applied Insulation

Refrigeration equipment must be provided with factory installed insulation on surfaces subject to sweating including the suction line piping. Where motors are the gas-cooled type, factory installed insulation must be provided on the cold-gas inlet connection to the motor in accordance with manufacturer's standard practice. Factory insulated items installed outdoors are not required to be fire-rated. As a minimum, factory insulated items installed indoors must have a flame spread index no higher than 75 and a smoke developed index no higher than 150. Factory insulated items (no jacket) installed indoors and which are located in air plenums, in ceiling spaces, and in attic spaces must have a flame spread index no higher than 25 and a smoke developed index no higher than 50. Flame spread and smoke developed indexes must be determined by ASTM E84. Insulation must be tested in the same density and installed thickness as the material to be used in the actual construction. Material supplied by a manufacturer with a jacket must be tested as a composite material. Jackets, facings, and adhesives must have a flame spread index no higher than 25 and a smoke developed index no higher than 50 when tested in accordance with ASTM E84.

2.7 TESTS, INSPECTIONS, AND VERIFICATIONS

All manufactured units must be inspected and tested, and documentation provided to demonstrate that each unit is in compliance with ANSI/AHRI and UL requirements and that the minimum efficiency requirements of ASHRAE 90.1 - IP have been met.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with all details of the work, perform Verification of Dimensions in the field, and advise the Contracting Officer of any discrepancy before performing any work.

3.2 INSTALLATION

Perform work in accordance with the manufacturer's published diagrams, recommendations, and equipment warranty requirements. Where equipment is specified to conform to the requirements of ASME BPVC SEC VIII D and ASME BPVC SEC IX, the design, fabrication, and installation of the system must conform to ASME BPVC SEC VIII D1 and ASME BPVC SEC IX.

3.2.1 Equipment

Provide refrigeration equipment conforming to ASHRAE 15 & 34. Provide necessary supports for all equipment, appurtenances, and pipe as required, including frames or supports for compressors, pumps, cooling towers, condensers, and similar items. Isolate compressors from the building structure. If mechanical vibration isolators are not provided, provide vibration absorbing foundations. Each foundation must include isolation units consisting of machine and floor or foundation fastenings, together with intermediate isolation material. Other floor-mounted equipment must be set on not less than a 6 inch concrete pad doweled in place. Concrete foundations for floor mounted pumps must have a mass equivalent to three

times the weight of the components, pump, base plate, and motor to be supported. In lieu of concrete pad foundation, concrete pedestal block with isolators placed between the pedestal block and the floor may be provided. Concrete pedestal block must be of mass not less than three times the combined pump, motor, and base weights. Isolators must be selected and sized based on load-bearing requirements and the lowest frequency of vibration to be isolated. Isolators must limit vibration to 10 percent at lowest equipment rpm. Provide lines connected to pumps mounted on pedestal blocks with flexible connectors. Provide foundation drawings, bolt-setting information, and foundation bolts prior to concrete foundation construction for all equipment indicated or required to have concrete foundations. Concrete for foundations must be as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE. Equipment must be properly leveled, aligned, and secured in place in accordance with manufacturer's instructions.

3.2.2 Mechanical Room Ventilation

Provide mechanical ventilation systems in accordance with Section 23 30 00 HVAC AIR DISTRIBUTION.

3.2.3 Field Applied Insulation

Apply field applied insulation as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS, except as defined differently herein.

3.2.4 Field Painting

Painting required for surfaces not otherwise specified, and finish painting of items only primed at the factory are specified in Section 09 90 00 PAINTS AND COATINGS.

3.3 CLEANING AND ADJUSTING

Equipment must be wiped clean, with all traces of oil, dust, dirt, or paint spots removed. Temporary filters must be provided for all fans that are operated during construction, and new filters must be installed after all construction dirt has been removed from the building. System must be maintained in this clean condition until final acceptance. Bearings must be properly lubricated with oil or grease as recommended by the manufacturer. Belts must be tightened to proper tension. Control valves and other miscellaneous equipment requiring adjustment must be adjusted to setting indicated or directed. Fans must be adjusted to the speed indicated by the manufacturer to meet specified conditions. Testing, adjusting, and balancing must be as specified in Section 23 05 93 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS.

3.4 TRAINING

Conduct a training course for the operating staff as designated by the Contracting Officer. The training period must consist of a total 8 hours of normal working time and start after the system is functionally completed but prior to final acceptance tests.

- a. Submit a schedule, at least 2 weeks prior to the date of the proposed training course, which identifies the date, time, and location for the training.
- b. Submit the field posted instructions, at least 2 weeks prior to

construction completion, including equipment layout, wiring and control diagrams, piping, valves and control sequences, and typed condensed operation instructions. The condensed operation instructions must include preventative maintenance procedures, methods of checking the system for normal and safe operation, and procedures for safely starting and stopping the system. The posted instructions must be framed under glass or laminated plastic and be posted where indicated by the Contracting Officer.

- c. The posted instructions must cover all of the items contained in the approved operation and maintenance manuals as well as demonstrations of routine maintenance operations. Submit 6 complete copies of an operation manual in bound 8-1/2 by 11 inch booklets listing step-by-step procedures required for system startup, operation, abnormal shutdown, emergency shutdown, and normal shutdown at least 4 weeks prior to the first training course. The booklets must include the manufacturer's name, model number, and parts list. The manuals must include the manufacturer's name, model number, service manual, and a brief description of all equipment and their basic operating features.
- d. Submit 6 complete copies of maintenance manual in bound 8-1/2 by 11 inch booklets listing routine maintenance procedures, possible breakdowns and repairs, and a trouble shooting guide. The manuals must include piping and equipment layouts and simplified wiring and control diagrams of the system as installed.

3.5 REFRIGERANT TESTS, CHARGING, AND START-UP

Split-system refrigerant piping systems must be tested and charged as specified in Section 23 23 00 REFRIGERANT PIPING. Packaged refrigerant systems which are factory charged must be checked for refrigerant and oil capacity to verify proper refrigerant levels in accordance with manufacturer's recommendations. Following charging, packaged systems must be tested for leaks with a halide torch or an electronic leak detector. Submit 6 copies of each test containing the information described below in bound 8-1/2 by 11 inch booklets. Individual reports must be submitted for the refrigerant system tests.

- a. The date the tests were performed.
- b. A list of equipment used, with calibration certifications.
- c. Initial test summaries.
- d. Repairs/adjustments performed.
- e. Final test results.

3.5.1 Refrigerant Leakage

If a refrigerant leak is discovered after the system has been charged, the leaking portion of the system must immediately be isolated from the remainder of the system and the refrigerant pumped into the system receiver or other suitable container. Under no circumstances must the refrigerant be discharged into the atmosphere.

3.5.2 Contractor's Responsibility

Take steps, at all times during the installation and testing of the refrigeration system, to prevent the release of refrigerants into the atmosphere. The steps must include, but not be limited to, procedures which will minimize the release of refrigerants to the atmosphere and the

use of refrigerant recovery devices to remove refrigerant from the system and store the refrigerant for reuse or reclaim. At no time must more than 3 ounces of refrigerant be released to the atmosphere in any one occurrence. Any system leaks within the first year must be repaired in accordance with the requirements herein at no cost to the Government including material, labor, and refrigerant if the leak is the result of defective equipment, material, or installation.

3.6 SYSTEM PERFORMANCE TESTS

Before each refrigeration system is accepted, conduct tests to demonstrate the general operating characteristics of all equipment by a registered professional engineer or an approved manufacturer's start-up representative experienced in system start-up and testing, at such times as directed. Six copies of the report provided in bound 8-1/2 by 11 inch booklets. The report must document compliance with the specified performance criteria upon completion and testing of the system. The report must indicate the number of days covered by the tests and any conclusions as to the adequacy of the system.

For equipment providing heating and cooling the system performance tests must be performed during the heating and cooling seasons.

- a. Submit a schedule, at least 2 weeks prior to the start of related testing, for the system performance tests. The schedules must identify the proposed date, time, and location for each test. Tests must cover a period of not less than 48 hours for each system and must demonstrate that the entire system is functioning in accordance with the drawings and specifications.
- b. Make corrections and adjustments, as necessary, tests must be re-conducted to demonstrate that the entire system is functioning as specified. Prior to acceptance, install and tighten service valve seal caps and blanks over gauge points. Replace any refrigerant lost during the system startup.
- c. If tests do not demonstrate satisfactory system performance, correct deficiencies and retest the system. Conduct tests in the presence of the Contracting Officer. Water and electricity required for the tests will be furnished by the Government. Provide all material, equipment, instruments, and personnel required for the test.
- d. Coordinate field tests with Section 23 05 93 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS. Submit 6 copies of the report provided in bound 8-1/2 by 11 inch booklets. The report must document compliance with the specified performance criteria upon completion and testing of the system. The report must indicate the number of days covered by the tests and any conclusions as to the adequacy of the system. Submit the report including the following information (where values are taken at least three different times at outside dry-bulb temperatures that are at least 5 degrees F apart):
 - (1) Date and outside weather conditions.
 - (2) The load on the system based on the following:
 - (a) The refrigerant used in the system.
 - (b) Condensing temperature and pressure.
 - (c) Suction temperature and pressure.

- (d) Ambient, condensing and coolant temperatures.
 - (e) Running current, voltage and proper phase sequence for each phase of all motors.
- (3) The actual on-site setting of operating and safety controls.
 - (4) Thermostatic expansion valve superheat - value as determined by field test.
 - (5) Subcooling.
 - (6) High and low refrigerant temperature switch set-points
 - (7) Low oil pressure switch set-point.
 - (8) Defrost system timer and thermostat set-points.
 - (9) Moisture content.
 - (10) Capacity control set-points.
 - (11) Field data and adjustments which affect unit performance and energy consumption.
 - (12) Field adjustments and settings which were not permanently marked as an integral part of a device.

3.7 MAINTENANCE

3.7.1 EXTRA MATERIALS

Submit spare parts data for each different item of equipment specified, after approval of detail drawings and not later than 2 months prior to the date of beneficial occupancy. Include in the data a complete list of parts and supplies, with current unit prices and source of supply, a recommended spare parts list for 1 year of operation, and a list of the parts recommended by the manufacturer to be replaced on a routine basis.

3.7.2 Maintenance Service

Submit a certified list of qualified permanent service organizations, which includes their addresses and qualifications, for support of the equipment. The service organizations must be reasonably convenient to the equipment installation and be able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

-- End of Section --

SECTION 23 82 16.00 40

AIR COILS
08/22

PART 1 GENERAL

Section 23 30 00 HVAC AIR DISTRIBUTION applies to work specified in this section.

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR-CONDITIONING, HEATING AND REFRIGERATION INSTITUTE (AHRI)

AHRI 410 (2001; Addendum 1 2002; Addendum 2 2005; Addendum 3 2011) Forced-Circulation Air-Cooling and Air-Heating Coils

ASTM INTERNATIONAL (ASTM)

ASTM A653/A653M (2023) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

ASTM B43 (2020) Standard Specification for Seamless Red Brass Pipe, Standard Sizes

ASTM B88 (2022) Standard Specification for Seamless Copper Water Tube

1.2 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Record of Existing Conditions

SD-02 Shop Drawings

Fabrication Drawings; G

Connection Diagrams; G

Controls Layout; G

Internal Tubing and Wiring; G

Installation Drawings; G

SD-03 Product Data

Steam Heating; G

Hot-Water Heating; G

Chilled-Water Cooling; G

Volatile Refrigerant Cooling; G

SD-05 Design Data

Design Analysis and Calculations

SD-06 Test Reports

Final Test Reports

SD-07 Certificates

Certificates of Conformance

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals

SD-11 Closeout Submittals

Record Drawings

1.3 QUALITY CONTROL

Submit a record of existing conditions consisting of the results of a survey of work area conditions and features of existing structures and facilities within and adjacent to the jobsite.

Provide coils that bear the ARI certification seal indicating compliance with AHRI 410. Submit Certificates of Conformance for following items showing conformance with AHRI 410:

- a. Coil
- b. Coil casings
- c. Coil headers
- d. Coil tubing
- e. Coil circuiting

Indicate the general physical controls layout, and internal tubing and wiring details on the drawings. Submit design analysis and calculations for coils.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

Submit manufacturer's catalog data for the following coil types indicating, when applicable, coil pressure and temperature ratings, coil casings, headers, tubing, circuiting, and drainable coils.

- a. Steam heating
- b. Hot-water heating
- c. Chilled-water cooling
- d. Volatile refrigerant cooling

Submit fabrication drawings for coil units consisting of fabrication and assembly details to be performed in the factory. Include connection diagrams indicating the relations and connections of the following items:

- a. Coil
- b. Coil casings
- c. Coil headers
- d. Coil tubing
- e. Coil circuiting

2.1.1 Coil Pressure and Temperature Ratings

Provide coils designed for the following fluid operating pressures and temperatures:

<u>Service</u>	<u>Pressure (psi)</u>	<u>Temperature (Degrees F)</u>
Steam - low pressure	25	267
Steam - high pressure	150	366
Steam - superheated	350	500
Hot water	200	250
Chilled water	200	45
Volatile refrigerant	200	300

Air-pressure test coils under water at the following minimum pressures:

<u>Service</u>	<u>Pressure (psi)</u>
Steam	250
Hot water	250
Chilled water	250

<u>Service</u>	<u>Pressure (psi)</u>
Volatile refrigerant	400

2.2 COMPONENTS

2.2.1 Coil Casings

Provide coil casings that are mill-galvanized, 16-gage, minimum. Ensure sheet metal has not less than 1.25-ounces of zinc per square foot of two-sided metal surface conforming to ASTM A653/A653M. Provide a casing flanged on four sides for bolted assembly, except as otherwise specified.

Where coils are stacked, provide a double-bend construction casing.

Provide casings with end supports and top and bottom channels of rigid construction that provide allowance for thermal expansion and contraction. Coil supports, channels and blank-off plates shall be the same metal as the coil casing.

Provide duct-mounted reheat coil casings not over 36-inches in length, fabricated from a minimum 20-gage galvanized steel conforming to above specified requirements. Provide casings that are flanged or suitable for drive-slip assembly.

Provide coil mounting within the housing that is either fixed or slide-out type, except as otherwise specified. Provide slide-out type coils for ceiling-suspended package units, and for other package units whose capacity exceeds 15,000 cubic-feet per minute.

2.2.2 Coil Headers

Provide direct expansion, volatile refrigerant coils with necessary control connections.

Fit steam and water coil headers with 1/4-inch iron pipe size(ips) spring-loaded plug drains and vent petcocks. Provide automatic vents where indicated.

2.2.3 Coil Tubing

Install coils constructed of copper tubing with aluminum or copper fins. Provide helical coil fins that are wound tight to the tubes and solder-coated. Provide plate fins that have spacer collars in metallic contact with the adjacent fin. Plate fins shall be continuous. Ensure fins are mechanically bonded to the tube. Ensure bare tube surface is not visible within the finned portion of the coil.

Provide solder-coated cooling coils of helical wound copper design.

For coil tubes in water or volatile refrigerant service, provide tubes that are parallel. Ensure coil tubes have sufficient intermediate full coil depth supports to prevent sagging of unsupported span due to: working fluid pressures, temperatures, and summer and winter coil-ambient conditions. Sagging is unacceptable if tube centerline is displaced by more than 3/16-inch from centerline of tube connection at outlet header when coils are more than two rows deep and when installed in accordance

with the manufacturer's instructions. Make adequate provision for expansion and contraction that precludes sagging and distortion under thermal loads applied in indicated or specified service. Slope tubes to be free draining.

Provide maximum heating-coil face tube spacing of 3-inches on center for 1-inch outside-diameter (od) tubes, 2-inches for 3/4-inch od tubes, and 1-1/2-inches for 5/8-inch od tubes.

Provide coil face tube spacing for cooling coils and for helically wound heating coils immediately followed by water-cooling coils that do not exceed 1-1/2-inches on center.

Ensure tubes are straight, with turns made through headers or return U-bends, with brazed connections and joints, except as otherwise specified.

Ensure coil tube material is seamless deoxidized copper.

Ensure coil tube material is seamless 90-10 copper-nickel with 0.035-inch wall thickness for superheated-steam service to 350-pounds per square inch (psi) at 500 degrees F.

Provide raw coil tube stock wall with a minimum thickness of 0.025-inch.

Provide raw coil tube stock wall with a minimum thickness of 0.035-inch.

Where mechanical insert devices are used to increase liquid turbulence within tubes, increase the wall thickness of these tubes by 0.010-inch over the minimum raw coil tube stock specified for the service.

Provide minimum tube outside diameter of 1/2-inch.

2.2.4 Coil Circuiting

Provide standard or full-circuited water coils that have as many full-length tubes in each circuit as the number of tubes in the depth of the coil face.

Provide counterflow type coils when more than two rows deep, except that in the case of double- or half-circuit coils, reasonable deviation from counterflow arrangement is permitted, provided the pressure drop and capacity requirements are met.

2.2.5 Drainable Coils

Provide drainable coils that are capable of being purged free of water with compressed air.

Provide self-draining coils with a drain point at the end of every tube and sloped to that point. Provide drain provisions that include: drained headers, U-bends with integral plugs; or nonferrous plugs in cast-iron headers. Provide tubes that drain substantially dry by gravity alone when drains and vents are open.

Where necessary, fill the coil with water to the end of the manufacturer's header connections and check drainage volume against the manufacturer's data.

2.2.6 Coil Types

2.2.6.1 Hot-Water Heating

Casings shall be minimum 16-gauge, galvanized steel.

Coil headers shall be Type L seamless copper conforming to ASTM B88, with tubes brazed to header.

Coil connections shall be Schedule 40 red brass conforming to ASTM B43, threaded end for 2-inch and smaller and flanged end for 2-1/2-inch and larger.

2.2.6.2 Volatile Refrigerant Cooling

For Type DX, provide counterflow type, designed for use with refrigerant specified, with equal length circuiting arrangement. Provide the number of distributors that suit indicated refrigerant and that eliminate trapping of refrigerant and oil. Obtain coil capacity with an expansion valve set for not less than 8 degrees F of superheat. Provide a refrigerant distributor that is furnished and installed by the coil manufacturer. Provide a tube outside diameter that is either 5/8-inch or 3/4-inch.

Coils shall be constructed of 1/2-inch OD min. seamless copper tubes with aluminum fins and tested at 250 psi prior to dehydration after which they are to be purged and sealed with inert gas prior to shipment.

Suction header shall be constructed of extra heavy seamless copper tubing.

Distributors shall be low pressure drop Venturi type design with male sweat connection to distribute refrigeration equally to multiple circuits.

Provide refrigerant distributor that is suitable for the thermostatic expansion valve recommended by the manufacturer for the service and capacity specified or indicated. Ensure arrangement is capable of stable operation down to 40 percent or less of design capacity.

PART 3 EXECUTION

3.1 INSTALLATION

Install coils in accordance with the manufacturer's recommendations.

Submit installation drawings for coil systems. Indicate overall physical features, dimensions, ratings, service requirements, equipment weights and layout and arrangement details of equipment room on drawings.

Clean oil film from coil fins with hot water/detergent as recommended by coil manufacturer.

Comb out fins when bent or crushed before enclosing coils in housing. Clean dust and debris from each coil to ensure its cleanliness.

Provide offsets in piping and physical space adjacent to the installed coil to facilitate coil removal.

Provide flexible piping connections and/or piping vibration isolation supports where specified or shown.

Provide where indicated cooling coils with 1-1/2-inch deep welded stainless steel drain pans. Drain pans shall be an integral part of the coil support. Provide condensate drain piping with drain traps to the indicated drain location.

3.2 FIELD QUALITY CONTROL

For drainable coils:

- a. Field check coil pitch and leveling for drainability in the presence of the Contracting Officer.
- b. Perform pressure tests and dehydrate coils.
- c. Perform vacuum tests, purge with inert gas, and seal coils.

Provide final test reports to the Contracting Officer. Provide reports with a cover letter/sheet clearly marked with the System name, Date, and the words "Final Test Reports - Forward to the Systems Engineer/Condition Monitoring Office/Predictive Testing Group for inclusion in the Maintenance Database."

3.3 CLOSEOUT ACTIVITIES

3.3.1 Operation and Maintenance

Submit 6 copies of the operation and maintenance manuals 30 calendar days prior to testing the coil systems. Update and resubmit data for final approval no later than 30 calendar days prior to contract completion.

3.3.2 Record Drawings

Submit record drawings for coil systems providing current factual information including deviations from, and amendments to, the drawings and concealed and visible changes in the work.

-- End of Section --

SECTION 25 05 11.01

CYBERSECURITY FOR LOW IMPACT HVAC CONTROL SYSTEMS
05/21, CHG 1: 08/23

PART 1 GENERAL

Many subparts in this Section contain text in curly braces ("{" and "}") indicating which cybersecurity control and control correlation identifier (CCI) the requirements of the subpart relate to. The text inside these curly braces is for Government reference only and enables coordination of the requirements of this Section with the RMF process throughout the design and construction process. Text in curly braces are not contractor requirements.

This Section refers to Security Requirements Guide (SRGs) and Security Technical Implementation Guide (STIGs). STIGs and SRGs are available online at the Information Assurance Support Environment (IASE) website at <https://public.cyber.mil/stigs/downloads/> and an SRG/STIG Applicability Guide and Collection Tool is available at <https://public.cyber.mil/stigs/SCAP/>. Not all control system components have applicable STIGs or SRGs. The "Control Systems SRG" does not apply to work performed under this Section; all requirements within this section to apply applicable SRGs DO NOT include the "Control Systems SRG".

1.1 CONTROL SYSTEM APPLICABILITY

There are multiple versions of this Section associated with this project. Different versions have requirements applicable to different control systems. This specific Section applies only to the following control systems: Low Impact HVAC Control System.

1.2 RELATED REQUIREMENTS

This section does not contain sufficient requirements to procure a control system and must be used in conjunction with other Sections which specify control systems. This Section adds cybersecurity requirements to the control systems specified in other Sections, and as these requirements are conditioned on the control system being provided, there may be requirements in this Section that will not apply to this project. All Sections containing facility-related control systems or control system components are related to the requirements of this Section. Review all specification sections to determine related requirements.

In cases where a requirement is specified in both this Section and in another Section, the more stringent requirement must be met. In cases where a requirement in this Section conflicts with the requirements of another Section such that both requirements cannot be met at the same time, request direction from the Contracting Officer Representative to determine which requirement applies to the project.

1.3 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE 135 (2020; Interpretation 1-8 2021; Errata 1-2 2021; Addenda CD 2021; Addenda BV-CE 2022; Interpretation 9-12 2022; Interpretation 13-24 2023; Addenda BV-CF 2023; Errata 3 2023) BACnet-A Data Communication Protocol for Building Automation and Control Networks

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 802.1x (2010) Local and Metropolitan Area Networks - Port Based Network Access Control

INTERNET ENGINEERING TASK FORCE (IETF)

IETF RFC 2819 (2000) Remote Network Monitoring (RMON) Management Information Base (MIB)

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST FIPS 140-2 (2001) Security Requirements for Cryptographic Modules

NIST FIPS 201-2 (2013) Personal Identity Verification (PIV) of Federal Employees and Contractors

U.S. DEPARTMENT OF DEFENSE (DOD)

DODI 8551.01 (2014) Ports, Protocols, and Services Management (PPSM)

DTM 08-060 (2008) Policy on Use of Department of Defense (DoD) Information Systems - Standard Consent Banner and User Agreement

1.4 DEFINITIONS

1.4.1 Administrator Account

An administrator account is an account with full permissions to a device, application, or operating system, including the ability to create and modify other user accounts.

Note that the operating system Administrator Account may be different than Administrator Accounts for applications hosted on that operating system. Also, most controllers will not have any support for accounts and will therefore not have an 'Administrator Account'.

1.4.2 Computer

A computer is one of the following:

- a. a device running a non-embedded desktop or server version of Microsoft Windows
- b. a device running a non-embedded version of MacOS
- c. a device running a non-embedded version of Linux
- d. a device running a version or derivative of the Android Operating System, where Android is considered separate from Linux
- e. a device running a version of Apple iOS

Unless otherwise indicated or clear from context use of the word "device" in this Section includes computers.

1.4.3 Controller

A device other than a computer or Ethernet switch.

1.4.4 Mission Space

A device or media is in mission space if physical access to the device or media is controlled by the organization served by the device. For example, a VAV box controller in a suspended ceiling is in mission space if the VAV box serves that room; an electrical switchgear in an electrical room or an AHU in a mechanical room or on a rooftop may still be considered to be in mission space if the organization (mission) served by that switchgear or AHU controls access to the electrical room, mechanical room or rooftop.

1.4.5 Network

A network is a group of two or more devices that can communicate using a network protocol. Network protocols must provide a method for addressing devices on the network; a communication method that does not provide an addressing scheme is not a networked form of communication. Devices that communicate using a method of communication that does not support device addressing are not using a network.

1.4.6 Network Connected

A component is network connected (or "connected to a network") only when the device has a network transceiver which is directly connected to the network and implements the network protocol. A device lacking a network transceiver (and accompanying protocol implementation) can never be considered network connected. Note that (unlike many IT definitions of "Network Connected") a device connected to a non-IP network is still considered network connected (an IP connection or IP address is not required for a device to be network connected).

1.4.6.1 Wireless Network Connected

Any device that supports wireless network communication is network connected to a wireless network, regardless of whether the device is communicating using wireless. Unless physically disabled, devices with wireless transceivers support wireless, it is not sufficient to disable the wireless in software.

1.4.7 Network Media

The thing that provides the communication channel between the devices on a network. Typically wire, but might include wireless, fiber optic, or even power line (some network protocols allow sending network signals over power wiring).

1.4.8 User Account Support Levels

The support for user accounts is categorized in this Section as one of three levels:

1.4.8.1 FULLY Supported

Device supports configurable individual accounts. Accounts can be created, deleted, modified, etc. Privileges can be assigned to accounts. These devices support user-based (as opposed to role-based) authentication.

1.4.8.2 MINIMALLY Supported

Device supports a small, fixed number of accounts (perhaps only one). Accounts cannot be modified. A device with only a "User" and an "Administrator" account would fit this category. Similarly, a device with two PINs for logon - one for restricted and one for unrestricted rights would fit here (in other words, the accounts do not have to be the traditional "username and password" structure). These devices typically only support role-based authentication.

Examples of devices which MINIMALLY support accounts are a) a variable frequency drive with a single account which requires a PIN for access to configuration; and b) a room lighting control touchpad interface that has a single account.

1.4.8.3 NOT Supported

Device does not support any Access Enforcement therefore the whole concept of "account" is meaningless.

1.4.9 Manual Local Input

Manual Local Inputs are system analog or binary inputs that are adjustable by a person but are, by intrinsic hardware design, very limited in potential capabilities. Manual Local Inputs do not have touch screens or full keyboards, but may have a few buttons or dials to allow input. Manual Local Inputs do not have full graphic screens or dot-matrix displays, but may have simple lights (LEDs) or 7-segment displays. Manual Local Inputs do not have any sort of menu structure, each button has a single well-defined function.

Examples of Manual Local Inputs are H-O-A switches, simple thermostats, and disconnect switches.

1.4.10 Card Reader

A card reader is an input/output device whose primary function is to assist in two-factor authentication. A card reader must have an interface to read data from a card and may be able to write data to a card. A card reader may have a means (such as buttons, keypad, touchscreen, etc.) for a user to input a PIN or password, as well as a limited display.

1.4.11 User Interface

A User Interface (UI) is something other than a Manual Local Input or Card Reader that allows a person to interact with the system or device. Note that while a Card Reader is not by itself a User Interface, a User Interface may contain a Card Reader in order for it to authenticate its user. Within control systems, there are a wide range of User Interfaces.

Two important distinctions are 1) whether the user interface is Local or Remote, and 2) the effective capabilities of the User Interface to alter data, which is the "privilege" of the user interface (where effective privilege available to a specific user at a specific user interface is the combination of the greatest privilege offered by the user interface and the specific account the user is logged into).

1.4.11.1 Local User Interface

A Local User Interface is a user interface where the physical hardware the user interacts with (keyboard, buttons, display, etc.) is physically part of the device being affected. All of the relevant characteristics of the user interface are embodied within a single device.

Note that a Local UI may be able to access data in a different device, Local versus Remote in this context refers to the user interface itself; the capability to access data in a different device is covered under "Full User Interface".

1.4.11.2 Remote User Interface

A Remote User Interface implements a Client/Server model where the physical hardware the user interacts with (Client) is physically distinct from the device being affected (Server). Most or all of the security and functionality characteristics of the user interface are defined by the Server, not the Client. The Client and Server communicate via a network connection. A common example of a remote user interface is a web-based interface where the browser (client) is generally on different hardware than the web server (server). A Remote UI remains a Remote UI even if the user happens to be at a Client on the same hardware as the Server. What is important is that a) the Client may be on different hardware than the Server and b) the majority of the security and functional characteristics of the interface are defined at the Server.

Note that this definition of "remote" is consistent with that generally used in the control industry but is not aligned with the NIST 800-53 definition of "Remote", which refers to "outside the system". The term "Remote" here better aligns with the NIST 800-53 definition of "Network" (remote from within the system) Access.

1.4.11.3 Types of User Interface (by capability)

User interfaces are also categorized by their capabilities as being Read Only, Limited, or Full.

1.4.11.3.1 Read-Only User Interface

A Read Only User Interface (also referred to as a View-Only User Interface) is a user interface that only allows for reading data, it does not allow (have the capability to) modify data. A Read Only User Interface may be either Local or Remote. A User Interface that is configured to be Read Only (by some other means than the interface itself, such as using configuration software on a laptop) is a Read-Only Interface. Note a Read Only User Interface may have buttons (or touch screen, etc.) allowing the user to navigate through the presentation of data.

Examples of a Read Only User Interfaces are a) a publicly viewable "energy dashboard" showing weather data and energy usage within a building and b) digital wayfinding signage.

1.4.11.3.2 Limited User Interface

A Limited User Interface is a user interface that - by design - can only alter information local to the user interface. Note that the determination of "alter" includes only direct interactions, it explicitly excludes interactions that might occur as secondary effects. For example, an interface changing the flow setpoint in a pump controller is a direct interaction, the subsequent change in flow (as well as any subsequent downstream changes in valve position) are not direct interactions.

Two examples of LIMITED UIs are: a) a variable speed drive has a Limited Local User Interface which allows the user to change properties within the drive, but does not allow affecting things outside the drive; and b) a typical home WiFi Router has a Limited Remote User Interface which allows configuration of the Router, but does not allow direct interaction with other devices.

1.4.11.3.3 Full User Interface

A Full User Interface can alter information in devices outside the device with the user interface. For example, a typical Local Display Panel is a Full Local User Interface while a browser-based front end is a Full Remote User Interface.

1.4.11.3.4 View-Only User Interface

See Read-Only User Interface

1.4.11.4 Other User Interface Terminology

In addition to defining whether a user interface is a Hardware Limited, Read-Only, Limited or Full, and whether it is Local or Remote, user interfaces are classified by whether they are writable or privileged.

1.4.11.4.1 Writable User Interface

Any User Interface that is not Read-Only is Writable. (Limited User Interfaces and Full User Interfaces are both writable user interfaces (as

they are capable of changing a value)).

1.4.11.4.2 Privileged User Interface

A Privileged UI is a UI that has sufficient capabilities or functionality that it requires specific cybersecurity measures to be put in place to limit its unauthorized use. Ultimately, whether a specific user interface is considered a Privileged User Interface must be determined by usage. Unless otherwise specified, user interfaces can be determined to be privileged or not using the following:

- a. Read-Only User Interfaces are not privileged user interfaces.
- b. Full User Interfaces are privileged user interfaces.
- c. User interfaces that allow for configuration of auditing or allows for modification or deletion of audit logs are privileged user interface.
- d. User interfaces that allow for reprogramming a network connected device is a privileged user interface.
- e. Except as specified above, a Limited User Interface must be determined to be privileged or not based on the specific capabilities and use case of the user interface. In general however, user interfaces that do not offer significant capabilities above and beyond those available at that location via other means (e.g. such as a disconnect switch, breaker, or hand-off-auto switch, or physical attack) are not privileged.

1.4.12 Wireless Network

Any network that communicates without using wires or fiber optics as the communication media. Wireless networks include: WiFi, Bluetooth, ZigBee, cellular, satellite, 900 MHz radio, 2.4 GHz, free space optical, point-to-point laser, and IR.

1.4.13 Wired Broadcast Network

Wired Broadcast Networks are any network, such as powerline carrier networks and modem (wired telephony), that use wire-based technologies where there is not a clearly defined boundary for signal propagation.

1.5 ADMINISTRATIVE REQUIREMENTS

1.5.1 Points of Contact

Coordinate with the following Points of Contact as indicated in this Section and as required. Not all projects will require coordination with all Points of Contact. When coordination is required and no Point of Contact is indicated, coordinate with The Contracting Office Representative (COR).

- a. Government Computer Access Point of Contact: The Contracting Office Representative (COR)
- b. HTTPS Certificate Point of Contact: The Contracting Office Representative (COR)

- c. Email Address Point of Contact: The Contracting Office Representative (COR)
- d. Password Point of Contact: The Contracting Office Representative (COR)
- e. Mobile Code Point of Contact: The Contracting Office Representative (COR)
- f. PKI Infrastructure Point of Contact: The Contracting Office Representative (COR)

1.5.2 Coordination

Coordinate the execution of this Section with the execution of all other Sections related to control systems as indicated in the paragraph RELATED REQUIREMENTS. Items that must be considered when coordinating project efforts include but are not limited to:

- a. If requesting permission for wireless or wired broadcast communication, the Wireless and Wired Broadcast Communication Request submittal must be approved prior to control system device selection and installation.
- b. If requesting permission for alternate account lock permissions, the Device Account Lock Exception Request must be approved prior to control system device selection and installation.
- c. If requesting permission for the use of a device with multiple physical connections to IP networks, the Multiple IP Connection Device Request must be approved prior to control system device selection and installation.
- d. Wireless testing may be required as part of the control system testing. See requirements for the Wireless Communication Test Report submittal.
- e. If the Device Audit Record Upload Software is to be installed on a computer not being provided as part of the control system, coordination is required to identify the computer on which to install the software.
- f. The Cybersecurity Interconnection Schedule must be coordinated with other work that will be interconnected to, and interconnections must be approved by the Government before relying on them for system functionality.
- g. Cybersecurity testing support must be coordinated across control systems and with the Government cybersecurity testing schedule.
- h. Passwords must be coordinated with the indicated contact for the project site.
- i. If applicable, HTTPS web server certificates must be obtained from the indicated HTTPS Certificate Point of Contact.
- j. Contractor Computer Cybersecurity Compliance Statements must be provided for each contractor using contractor owned computers.

1.6 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Wireless and Wired Broadcast Communication Request; G
Device Account Lock Exception Request; G

Multiple Ethernet Connection Device Request; G

Contractor Computer Cybersecurity Compliance Statements; G

Contractor Temporary Network Cybersecurity Compliance Statements; G

Cybersecurity Interconnection Schedule; G
Proposed STIG and SRG Applicability Report; G

SD-02 Shop Drawings

Network Communication Report; G

Cybersecurity Riser Diagram; G

SD-03 Product Data

Control System Cybersecurity Documentation; G

SD-06 Test Reports

Wireless Communication Test Report; G

Control System Cybersecurity Testing Procedures; G

Control System Cybersecurity Testing Report; G

SD-07 Certificates

Software Licenses; G

SD-11 Closeout Submittals

Password Change Summary Report; G

Enclosure Keys; G

Software and Configuration Backups; G

Auditing Front End Software; G

Device Audit Record Upload Software; G

System Maintenance Tool Software; G

Control System Scanning Tools; G

STIG, SRG and Vendor Guide Compliance Result Report; G

Control System Inventory Report; G

1.7 QUALITY CONTROL

1.7.1 Cybersecurity Subject Matter Expert Qualifications

For the Low Impact HVAC control system: For the position listed below resumes should be submitted to the Government within 14 days after notice to proceed. All certifications must be in effect prior to being hired.

These positions may serve across the contract and provide on-site support as required..

1.7.1.1 Cybersecurity Subject Matter Expert

The individual will over see all work within these specification. This position requires that the individual currently meets Information Assurance Management Level II Certification in accordance with DODD 8140 Cybersecurity Workforce Management and DODI 8570 Information Workforce Improvement Program.

Individuals for this position should have experience securing DoD Systems and with Risk Management Framework

1.8 CYBERSECURITY DOCUMENTATION

{For Government Reference Only: This subpart (and its subparts) relates to PL-7; CCI-003071}

1.8.1 Proposed STIG and SRG Applicability Report

For each model of network connected or network infrastructure device, use the DISA SRG/STIG Applicability Guide and Collection Tool (available at <https://public.cyber.mil/stigs/SCAP/>) to identify applicable STIGs or SRGs and provide a report indicating applicable STIGs and SRGs for each model.

1.8.2 Cybersecurity Interconnection Schedule

{For Government Reference Only: This subpart relates to CA-3(b), PL-8, SC-7(9), SC-7(11); CCI-000258, CCI-003072, CCI-003073, CCI-003075, CCI-002398, CCI-002399, CCI-002401, CCI-002402, CCI-002403.}

Provide a completed Cybersecurity Interconnection Schedule documenting network connections between the installed system and other systems. Provide the following information for each device directly communicating between systems: Device Identifier, Device Description, Transport layer Protocol, Network Address, Port (if applicable), MAC (Layer 2) address (if applicable), Media, Application Protocol, Service (if applicable), Descriptive Purpose of communication. For communication with other authorized systems also provide the Foreign Destination and POC for Destination. If other control system Sections used on this project include submittals documenting this information, provide copies of those submittals to meet this requirement.

In addition to the requirements of Section 01 33 00 SUBMITTAL PROCEDURES, provide the Cybersecurity Interconnection Schedule as an editable

Microsoft Excel file (a template Cybersecurity Interconnection Schedule in Excel format is available at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1>)

1.8.3 Network Communication Report

{For Government Reference Only: This subpart (and its subparts) relates to CA-9, PL-8; CCI-002102, CCI-002103, CCI-002104, CCI-002105, CCI-003072, CCI-003073, CCI-003075 and also the submittal requirements associated with CM-6, CM-7, SC-8 and SC-41 including CM-7(3), CCI-000388.}

Provide a network communication report. For each networked device, document the communication characteristics of the device including communication protocols, services used, encryption employed, and a general description of what information is communicated over the network. For each device using IP, document all TCP and UDP ports used. For non-IP communications, document communication protocol and media used. If other control system Sections used on this project include submittals documenting this information, provide copies of those submittals to meet this requirement.

In addition to the requirements of Section 01 33 00 SUBMITTAL PROCEDURES, provide the Network Communication Report as an editable Microsoft Excel file.

1.8.4 Control System Inventory Report

{For Government Reference Only: This subpart (and its subparts) relates to CM-8(a), SI-17, IA-3; CCI-000389, CCI-000392, CCI-000398, CCI-002773, CCI-002774, CCI-002775, CCI-000777, CCI-000778, CCI-001958}

Provide a Control System Inventory report using the Inventory Spreadsheet listed under this Section at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1> documenting all devices, including networked devices, network infrastructure devices, non-networked devices, input devices (e.g. sensors) and output devices (e.g. actuators). For each device provide all applicable information for which there is a field on the spreadsheet in accordance with the instructions on the spreadsheet.

In addition to the requirements of Section 01 33 00 SUBMITTAL PROCEDURES, provide the Control System Inventory Report as an editable Microsoft Excel file.

1.8.5 Software and Configuration Backups

{For Government Reference Only: This subpart (and its subparts) relates to CP-10; CCI-000550, CCI-000551, CCI-000552}

For each computer on which software is installed under this project, provide a recovery image of the final as-built computer. This image must allow for bare-metal restore such that restoration of the image is sufficient to restore system operation to the imaged state without the need for re-installation of software. If additional user permissions are required to meet this requirement, coordinate the creation of the image with the identified Government Computer Access Point of Contact.

For all ethernet switches provide a backup of the switch configuration. For all controllers, provide a backup of the controller configuration and the source code for all loaded application programs (all software that is not common to every controller of the same manufacturer and model).

If any or all of these are provided under another Section, provide documentation indicating this and referencing those submittals.

1.8.6 Cybersecurity Riser Diagram

{For Government Reference Only: This subpart (and its subparts) relates to PL-2(a), PL-8; CCI-003051, CCI-003053, CCI-003072, CCI-003073, CCI-003075}

Provide a cybersecurity riser diagram of the complete control system including all network and device hardware. If the control system specifications require a riser diagram submittal, provide a copy of that submittal as the cybersecurity riser diagram. Otherwise, provide a riser diagram in one-line format.

1.8.7 STIG, SRG and Vendor Guide Compliance Result Report

For every component (device or software) with an applicable STIG or SRG in the Proposed STIG and SRG Applicability Report, provide a result report documenting compliance with the STIG or SRG requirements. For components which are scannable by the SCAP (security content automation protocol) tool (available online at <https://public.cyber.mil/stigs/scap>), provide the SCAP report and raw scan results.

For every component (device or software) with manufacturer provided cybersecurity documentation, procedure, or method for secure configuration or installation, provide a report documenting how the component was configured and any deviation from the manufacturer instructions.

1.8.8 Control System Cybersecurity Documentation

{For Government Reference Only: This subpart (and its subparts) relates to SA-5(a), SA-5(b), SA-5(c), SA-22(b); CCIs: CCI-003124, CCI-003125, CCI-003126, CCI-003127, CCI-003128, CCI-003129, CCI-003130, CCI-003131, CCI-003374}

Provide a Control System Cybersecurity Documentation submittal containing the indicated information for each device and software application.

1.8.8.1 Software Applications

For all software applications running on computers provide:

- a. administrator documentation that describes secure configuration of the software {For Government Reference Only: relates to CCI-003124}
- b. administrator documentation that describes secure installation of the software and software updates. {For Government Reference Only: relates to CCI-003125}
- c. administrator documentation that describes secure operation of the software {For Government Reference Only: relates to CCI-003124}

- d. administrator documentation that describes effective use and maintenance of security functions or mechanisms for the software {For Government Reference Only: relates to CCI-003127}
- e. administrator documentation that describes known vulnerabilities regarding configuration and use of administrative (i.e. privileged) functions for the software {For Government Reference Only: relates to CCI-003128}
- f. user documentation that describes user-accessible security functions or mechanisms in the software and how to effectively use those security functions or mechanisms {For Government Reference Only: relates to CCI-003129}
- g. user documentation that describes methods for user interaction which enables individuals to use the software in a more secure manner {For Government Reference Only: relates to CCI-003130}
- h. user documentation that describes user responsibilities in maintaining the security of the software {For Government Reference Only: relates to CCI-003131}

1.8.8.2 For HVAC Control System Devices

1.8.8.2.1 HVAC Control System Devices FULLY Supporting User Accounts

For all HVAC Control System Devices which FULLY support user accounts, provide:

- a. Documentation that describes secure configuration of the device {For Government Reference Only: relates to CCI-003124}
- b. Documentation that describes secure operation of the device {For Government Reference Only: relates to CCI-003124}
- c. Documentation that describes effective use and maintenance of security functions or mechanisms for the device {For Government Reference Only: relates to CCI-003127}
- d. Documentation that describes known vulnerabilities regarding configuration and use of administrative (i.e. privileged) functions for the device {For Government Reference Only: relates to CCI-003128}
- e. Documentation that describes user-accessible security functions or mechanisms in the device and how to effectively use those security functions or mechanisms; or a specific indication that there are no user-accessible security functions or mechanisms in the device {For Government Reference Only: relates to CCI-003129}
- f. Documentation that describes methods for user interaction which enables individuals to use the device in a more secure manner {For Government Reference Only: relates to CCI-003130}

1.8.8.2.2 All Other HVAC Control System Devices

For all HVAC Control System Devices which do not FULLY support user accounts, provide:

- a. Documentation that describes secure configuration of the device; or a specific indication that there are no secure configuration steps that apply {For Government Reference Only: relates to CCI-003124}
- b. Documentation that describes effective use and maintenance of security functions or mechanisms for the device; or a specific indication that there are no security functions or mechanisms in the device {For Government Reference Only: relates to CCI-003127}
- c. For devices which include a user interface, documentation that describes methods for user interaction which enables individuals to use the device in a more secure manner {For Government Reference Only: relates to CCI-003130}

1.8.8.3 Default Requirements for Control System Devices

For control system devices where Control System Cybersecurity Documentation requirements are not otherwise indicated in this Section, provide:

- a. Documentation that describes secure configuration of the device {For Government Reference Only: relates to CCI-003124}
- b. Documentation that describes secure installation of the device {For Government Reference Only: relates to CCI-003125}
- c. Documentation that describes secure operation of the device {For Government Reference Only: relates to CCI-003124}
- d. Documentation that describes effective use and maintenance of security functions or mechanisms for the device {For Government Reference Only: relates to CCI-003127}
- e. Documentation that describes known vulnerabilities regarding configuration and use of administrative (i.e. privileged) functions for the device {For Government Reference Only: relates to CCI-003128}
- f. Documentation that describes user-accessible security functions or mechanisms in the device and how to effectively use those security functions or mechanisms {For Government Reference Only: relates to CCI-003129}
- g. Documentation that describes methods for user interaction which enables individuals to use the device in a more secure manner {For Government Reference Only: relates to CCI-003130}
- h. Documentation that describes user responsibilities in maintaining the security of the device {For Government Reference Only: relates to CCI-003131}
- i. Documentation of the published last date of support by the manufacturer or indication that a published date is not available. {For Government Reference Only: relates to CCI-003374}

1.9 SOFTWARE LICENSING

{For Government Reference Only: This subpart (and its subparts) relates to SI-2(a), SI-2(c), SI-7(14); CCI-001227, CCI-002605, CCI-002737}

For all software provided that has not already been licensed to the government or project site, provide a license to the Government for a period of no less than 5 years, and the license must also include the following software updates:

- a. Security and bug-fix patches issued by the software manufacturer.
- b. Security patches to address any vulnerability identified in the National Vulnerability Database at <http://nvd.nist.gov> with a Common Vulnerability Scoring System (CVSS) severity rating of MEDIUM or higher.

Provide a single Software Licenses submittal with documentation of the software licenses for all software provided

1.10 CYBERSECURITY DURING CONSTRUCTION

{For Government Reference Only: This subpart (and its subparts) relates to AC-18, SA-3; CCI-000258}

In addition to the control system cybersecurity requirements indicated in this section, meet following requirement throughout the construction process.

1.10.1 Contractor Computer Equipment

Contractor owned computers may be used for construction. Contractor computers connected to the control system, control system network, or a control system component at any point during construction must meet the following requirements:

1.10.1.1 Operating System

The operating system must be an operating system currently supported by the manufacturer of the operating system. The operating system must be current on security patches and operating system manufacturer required updates.

1.10.1.2 Anti-Malware Software

The computer must run anti-malware software from a reputable software manufacturer. Anti-malware software must be a version currently supported by the software manufacturer, must be current on all patches and updates, and must use the latest definitions file. Computers used on this project must be scanned using the installed software at least once per day.

1.10.1.3 Passwords and Passphrases

The passwords and passphrases for computers, applications, and web-based applications supporting passwords must be changed from their default values. Passwords must be a minimum of eight characters with a minimum of one uppercase letter, one lowercase letter, one number and one special character.

1.10.1.4 User-Based Authentication

Each user must have a unique account; sharing of a single account between multiple users is prohibited.

1.10.1.5 Demonstration of Compliance

The Government has the right to require demonstration of computer compliance with these requirements at any time during the project.

1.10.1.6 Contractor Computer Cybersecurity Compliance Statements

Provide a single submittal containing completed Contractor Computer Cybersecurity Compliance Statements for each company using contractor owned computers. Contractor Computer Cybersecurity Compliance Statements must use the template published at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1> Each Statement must be signed by a cybersecurity representative for the relevant company.

1.10.2 Temporary IP Networks

Temporary contractor-installed IP networks may be used during construction. When used, temporary contractor-installed IP networks connected to the control system, control system network, or a control system component at any point during construction must meet the following requirements:

1.10.2.1 Network Boundaries and Connections

The network must not extend outside the project site and must not connect to any IP network other than those specifically provided or furnished for this project. Any and all access to the network from outside the project site is prohibited.

1.10.3 Government Access to Network

Government personnel must be allowed to have complete and immediate access to the network at any time in order to verify compliance with this specification.

1.10.4 Temporary Wireless IP Networks

In addition to the other requirements on temporary IP networks, temporary wireless IP (WiFi) networks, when permitted, must not interfere with existing wireless networks, must use WPA2 security and must not broadcast the network name (SSID). Network names (SSID) for wireless networks must be changed from their default values.

1.10.5 Passwords and Passphrases

The passwords and passphrases for all network devices and network access must be changed from their default values. Passwords must be a minimum 8 characters with a minimum of one uppercase letter, one lowercase letter, one number and one special character.

1.10.6 Contractor Temporary Network Cybersecurity Compliance Statements

Provide a single submittal containing completed Contractor Temporary Network Cybersecurity Compliance Statements for each company implementing a temporary IP network. Contractor Temporary Network Cybersecurity Compliance Statements must use the template published at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1>. Each Statement must be signed by a cybersecurity representative for the relevant company. If no temporary IP networks will be used, provide a single copy of the Statement indicating this.

1.11 CYBERSECURITY DURING WARRANTY PERIOD

All work performed on the control system after acceptance must be performed using Government Furnished Equipment or equipment specifically and individually approved by the Government.

PART 2 PRODUCTS

All products used on this project must meet the indicated requirements, but not all products specified here will be required by every project.

2.1 ETHERNET SWITCH

Provide Open Systems Interconnection (OSI) Layer 2 Ethernet switches with the following capabilities, and with an interface to support switch configuration for these capabilities:

2.1.1 Required Functionality

Switches must:

- a. Copper Ethernet ports must auto negotiate for 10, 100 and 1000 megabits-per-second links.
- b. Be capable of implementing port level access control by MAC address and limit the number of MAC addresses to one MAC address per port.
- c. For LOW Impact Systems, be capable of implementing per-port access control lists (ACLs) where the list can be filtered by source and destination IP addresses, and by source and destination UDP or TCP ports.
- d. Support Remote Network Monitoring (RMON) Port Analysis in accordance with IETF RFC 2819
- e. Configure target port and analysis port such that switch clones all target port traffic to analysis port.

2.1.2 Configuration Requirements

Switches must:

- a. Support configuration save and restore.
- b. Support both manual IP address assignment and acquisition of a dynamic IP address via Dynamic Host Configuration Protocol (DHCP).

- c. Be capable of limiting access for configuration to one or more of: a web interface using HTTPS, a command line interface using SSH, or an SNMP connection using SNMP version 3 or later.
- d. Support the ability to lock configuration capability to a dedicated management port.

2.2 DAISY CHAIN IP CONTROLLERS

Controllers used as Daisy Chain IP Controllers must be IP controllers with exactly two Ethernet network connections and basic built-in switch capabilities to allow implementation of an Ethernet network in a daisy chain architecture. Switches incorporated by Daisy Chain IP Controllers are not required to meet the requirements for Ethernet Switches as defined in this Section.

PART 3 EXECUTION

3.1 CYBERSECURITY HARDENING AND CONFIGURATION GUIDES

Install, configure, and harden all hardware and software furnished on this project in accordance with manufacturer provided documentation, procedures, or methods for secure configuration or installation. Do not implement specific hardening actions if that action would conflict with required functionality or another requirement of this Section.

3.2 NETWORK REQUIREMENTS

3.2.1 Wireless and Wired Broadcast Communication

{For Government Reference Only: This subpart (and its subparts) relates to AC-18, AC-18(3); CCI-001438, CCI-001439, CCI-002323, CCI-001441, CCI-001449}

Unless explicitly authorized by the Government, do not use any wireless or wired broadcast communication. If requesting authorization for wireless or wired broadcast communication, wired broadcast media such as powerline carrier is preferred to wireless.

3.2.1.1 Wireless and Wired Broadcast IP Communications

Unless specifically approved and installed in accordance with the project site requirements, Do not install wireless or wired broadcast IP networks, including: do not install a wireless access point; do not install or configure an ad-hoc wireless network; do not install or configure a WiFi Direct communication.

When explicitly authorized by the Government, wireless IP communication may be used to communicate with an existing wireless network.

3.2.1.2 Non-IP Wireless Communication

For LOW Impact Systems: When non-IP wireless communication is explicitly authorized by the Government, use the maximum level of encryption supported by the specific protocol employed and select signal strength and radiated power to the minimum necessary for reliable communication.

3.2.1.3 Wireless and Wired Broadcast Communication Request

Provide a report documenting the proposed use of wireless or wired broadcast communication prior to device selection using the Wireless and Wired Broadcast Communication Request Schedule at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1>. If there is no proposed use of wireless or wired broadcast communication, provide a document indicating this instead of the Request Schedule.

For each device proposed to use wireless or wired broadcast communication show: the device identifier, a description of the device, the location of the device, the device identifiers of other devices communicating with the device, the protocol used for communication, encryption type and strength. For wireless communication, also show: RF Frequency, Radiated Power in dBm (decibel with a milliwatt reference), free-space range, and the expected as-installed range.

3.2.1.4 Wireless Communication Testing

As part of Performance Verification Testing (PVT), conduct testing of wireless communication for all devices indicated on the approved Wireless and Wired Broadcast Communication Request as requiring testing.

To test wireless communication, test for wireless network reception at multiple points along the wireless test boundary in the vicinity of the wireless device, and record whether a network connection can be established at each point. The wireless test boundary is the building exterior walls. If wireless testing is required, provide a Wireless Communication Test Report documenting the testing points and results at each point for each wireless device.

3.2.2 Non-IP Control Networks

When control system specifications require particular communication protocols, use only those communication protocols and only as specified. Do not implement any other communication protocol.

When control system specifications do not indicate requirements for communication protocols, use only those protocols required for operation of the system as specified.

3.2.3 IP Control Networks

{For Government Reference Only: This subpart relates to CM-6(a), CM-7(a), CM-7(b), CM-7(1)(b), SC-41; CCI-001588, CCI-000381, CCI-000380, CCI-000381, CCI-000382, CCI-001761, CCI-001762, CCI-002544, CCI-002545, CCI-002546.}

IP Networks must be Ethernet networks and must use switches which are Ethernet Switches or Daisy Chain IP Controllers as defined in this Section. Do not use nonsecure functions, ports, protocols and services as defined in DODI 8551.01 unless those ports, protocols and services are specifically required by the control system specifications or otherwise specifically authorized by the Government. Do not use ports, protocols and services that are not specified in the control system specifications or required for operation of the control system.

3.2.3.1 IP Network Routers

Do not install any device that performs IP routing.

3.2.3.2 IP Devices With Multiple Ethernet Connection

Except for Ethernet Switches and Daisy Chain IP Controllers, devices must not have more than one Ethernet connection to IP networks unless doing so is required by the project specifications and the specific application is approved. If a device with Multiple Ethernet Connections to IP networks is required, provide a Multiple Ethernet Connection Device Request using the Multiple Ethernet Connection Device Request Template at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1> to request approval for each device. If a device with Multiple Ethernet Connections to IP networks is not required, instead provide a document stating that no approval is being requested.

3.2.4 Cryptographic Protection

{For Government Reference Only: This subpart relates to IA-2(9), IA-3(1), SC-8, SC-13, SC-23(1), SC-23(3); CCI-001942, CCI-001959, CCI-001967, CCI-002418, CCI-002449, CCI-002450, CCI-001185, CCI-001188, CCI-001664.}

All remote user interfaces must use HTTPS for all traffic between the user interface client and user interface server.

For devices that have STIG/SRGs related to cryptographic protection (CCI-002450), comply with the requirements of those STIG/SRGs. Ensure that all network traffic is encrypted using NSA-approved cryptography; provision of digital signatures and hashing, and FIPS-validated cryptography.

3.2.5 Device Identification and Authentication

{For Government Reference Only: This subpart (and its subparts) relates to IA-3; CCI-000777, CCI-000778, CCI-001958.}

All computers must support and implement IEEE 802.1x for device authentication to the network.

3.2.5.1 For HVAC Control System Devices

Devices using HTTP as a control protocol must use HTTPS instead. Devices using BACnet must support network security as specified for BACnet Secure Connect in ASHRAE 135.

3.2.5.2 Default Requirements for Control System Devices

For control system devices where Device Identification and Authentication requirements are not otherwise indicated in this Section: Devices using HTTP as a control protocol must use HTTPS instead.

3.2.6 Cryptographic Module Authentication

{For Government Reference Only: This subpart (and its subparts) relates to IA-7; CCI-000803}

For devices (including but not limited to NIST FIPS 140-2 compliant radios) that have STIG/SRGs related to cryptographic module authentication (CCI-000803), comply with the requirements of those STIG/SRGs.

3.3 ACCESS CONTROL REQUIREMENTS

3.3.1 User Accounts

{For Government Reference Only: This subpart (and its subparts) relate to AC-2(a), AC-3, AC-6(1), AC-6(10), AC-6(2), AC-6(9), CM-11(2), and IA-2; CCI-002110, CCI-000213, CCI-001558, CCI-002221, CCI-002222, CCI-002223, CCI-002235, CCI-000039, CCI-001419, CCI-002234, CCI-001812, and CCI-000764.
}

Any user interface supporting user accounts (either FULLY or MINIMALLY) must limit access according to specified limitations for each account. Install and configure any device having a STIG or SRG in accordance with that STIG or SRG.

All user interfaces FULLY supporting accounts must implement user-based authentication where each account is uniquely assigned to a specific user. User interfaces FULLY supporting accounts must implement at least three (3) levels of user account privilege including: 1) an account with read-only permissions 2) an account with full permissions including account creation and modification and 3) an account with greater permissions than read-only but without account creation and modification.

3.3.1.1 Computers

All computer operating systems must FULLY support user accounts and implement accounts for access. Each control system software application not supporting accounts and running on a computer must be installed such that use of the software is restricted by the computer operating system to specific users.

Applications running on computers must not require the user be logged in to a computer operating system administrator account for normal operation. It is permissible to require the computer operating system administrator account for initial application installation and configuration.

3.3.1.2 Controllers

For user interfaces provided by controllers, provide access control in accordance with the User Interface Requirements table for the applicable control system and user interface type.

- a. For table entries of "NA": NA means Not Applicable, there are no interfaces in this category.
- b. For table entries of "None Required": The user interface is not required to support user accounts.
- c. For table entries of "MINIMALLY": The user interface must at least MINIMALLY support user accounts.

- d. For table entries of "FULLY": The user interface must at FULLY support user accounts.
- e. For table entries of "KEY": The user interface must have physical security in the form of either a key lock on the interface itself or be furnished inside a locked enclosure. Where this is required for a read only interface, this lock must prevent viewing of data on the interface; for other interfaces, this lock must prevent using the interface to alter data.
- f. For table entries of "Physical Security": For Local FULL interfaces, the interface must be located inside mission space. For Local Limited (not FULL) interfaces, the user interface must either a) be located within mission space or b) be protected by physical security at least as good as the control devices (and equipment controlled by the control devices) affected by the interface. For purposes of this requirement, 'affected' includes controllers with data that can be directly altered by the interface, as well as mechanical and/or electrical equipment directly controlled by those controllers, but does not include other interactions.
- g. Entries of the form "X and Y" must meet both the requirement indicated for X and the requirement indicated for Y. For example, an entry of "MINIMALLY and Physical Security" indicates the user interface must both MINIMALLY support accounts and have physical security.
- h. Entries of the form "X or Y" must meet either the requirement indicated for X or the requirement indicated for Y.

3.3.1.2.1 HVAC Control Systems

User Interface Requirements for LOW Impact HVAC Control Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u>
Local Read Only (see note 1)	None Required
Local Limited, Non-privileged	MINIMALLY
Local Limited, Privileged	Physical Security
Local Full	MINIMALLY
Remote Read Only	None Required
Remote Limited, Non-Privileged	MINIMALLY
Remote Limited, Privileged AND Remote Full (see note 2)	FULLY
Notes: 1)Local Read Only User Interfaces are always Non-Privileged 2)Remote Full User Interfaces are always Privileged	

3.3.1.2.2 Default Requirements for Other Control Systems

For control system devices where User Interface Requirements are not otherwise indicated in this Section, use the Default User Interface Requirements tables.

Default User Interface Requirements for LOW Impact Control Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u>
Local Read Only (see note 1)	None Required
Local Limited, Non-privileged	MINIMALLY
Local Limited, Privileged	Physical Security
Local Full	MINIMALLY
Remote Read Only	None Required
Remote Limited, Non-Privileged	MINIMALLY
Remote Limited, Privileged AND Remote Full (see note 2)	FULLY
Notes: 1)Local Read Only User Interfaces are always Non-Privileged 2)Remote Full User Interfaces are always Privileged	

3.3.2 Unsuccessful Logon Attempts

{For Government Reference Only: This subpart (and its subparts) relate to AC-7 (a), AC-7 (b); CCI-000043, CCI-000044, CCI-001423, CCI-002236, CCI-002237, CCI-002238}

Except for high availability user interfaces indicated as exempt, devices must meet the indicated requirements for handling unsuccessful logon attempts. If a device cannot meet these requirements, document device capabilities to protect from subsequent logon attempts and propose alternate protections in a Device Account Lock Exception Request submittal. Do not implement alternate protection measures in lieu of the indicated requirements without explicit permission from the Government. If no Device Account Lock Exceptions are requested, provide a document stating that no approval is being requested as the Device Account Lock Exception Request.

3.3.2.1 Devices MINIMALLY Supporting Accounts

For LOW Impact Systems: Devices which MINIMALLY (but not FULLY) support accounts are not required to lock based on unsuccessful logon attempts.

3.3.2.2 Devices FULLY Supporting Accounts

Devices which FULLY support accounts must meet the following requirements.

- a. It must lock the user account when three unsuccessful logon attempts occur within a 15 minute interval.
- b. Once an account is locked, the account must stay locked until unlocked by an administrator. If the account being locked is the sole administrator account on the device, the account must stay locked for 1 hour and then automatically unlock.
- c. Once the indicated number of unsuccessful logon attempts occurs, delay further logon prompts by 5 seconds.

3.3.2.3 High Availability Interfaces Exempt from Unsuccessful Logon Attempts Requirements

There are no high availability interfaces which are exempt from unsuccessful logon attempts requirements.

3.3.3 System Use Notification

{For Government Reference Only: This subpart (and its subparts) relates to AC-8; CCI-000048, CCI-002247, CCI-002243, CCI-002244, CCI-002245, CCI-002246, CCI-000050, CCI-002248}

3.3.3.1 System Use Notification for Remote User Interfaces

Remote user interfaces must display a warning banner meeting the requirements of DTM 08-060 on screen.

3.3.3.2 System Use Notification for Local User Interfaces

Devices which are connected to a network and have a local user interface must display a warning banner meeting the requirements of DTM 08-060 on the user interface screen if capable of doing so and must have a permanently affixed label with an approved banner from DTM 08-060 if unable to display the warning banner on the screen. Where it is impractical (perhaps due to device size) to affix the label to the device, affix the label to the device enclosure.

Labels must be machine printed or engraved, plastic or metal, designed for permanent installation, must use a font no smaller than 14 point, and must provide a high contrast between font and background colors.

3.3.4 Permitted Actions Without Identification or Authentication

{For Government Reference Only: This subpart (and its subparts) relates to AC-14; CCI-000061, CCI-000232}

The control system must require identification and authentication before allowing any actions except read-only actions by a user acting from a user interface which MINIMALLY or FULLY supports accounts.

3.3.5 Enclosures

Prior to final acceptance of the system, lock all lockable enclosures. Submit an Enclosure Keys submittal with all copies of keys for all enclosures and a key inventory list documenting all keys. Label each key with the matching enclosure identifier.

3.4 USER IDENTIFICATION AND AUTHENTICATION

{For Government Reference Only: This subpart (and its subparts) relates to IA-2, IA-2(1), IA-2(12), IA-5 IA-5(b), IA-5(c), IA-5(e), IA-5(g), IA-5(1), IA-5(11); CCI-000764, CCI-000765, CCI-001953, CCI-001954, CCI-001544, CCI-001989, CCI-000182, CCI-001610, CCI-000192, CCI-000193, CCI-000194, CCI-000205, CCI-001619, CCI-001611, CCI-001612, CCI-001613, CCI-001614, CCI-000195, CCI-001615, CCI-000196, CCI-000197, CCI-000199, CCI-000198, CCI-001616, CCI-001617, CCI-000200, CCI-001618, CCI-002041, CCI-002002, CCI-002003. }

This subpart indicates requirements for specific methods of identification and authentication for users and user accounts. Where these requirements conflict apply the following order of precedence: 1) If present, Device Specific Requirements take precedence over any other requirements; and then 2) multifactor authentication requirements take precedence over password requirements.

3.4.1 User Identification and Authentication for All System Types

Unless otherwise indicated, all user interfaces supporting accounts (either FULLY or MINIMALLY) must implement Identification and Authorization via passwords.

For LOW Impact Systems: User interfaces provided by computer operating systems must implement multifactor authentication via PIV.

3.4.2 User Identification and Authentication for Specific System Types

System specific requirements are in addition to and supersede those indicated for all system types. When no additional requirements are indicated for a specific system type the requirements for all systems still apply to that system type.

3.4.2.1 HVAC Control Systems Devices

No additional system specific requirements apply.

3.4.3 User Identification and Authentication for Specific Devices

There are no additional device specific user interface requirements

3.4.4 Implementation of Identification and Authorization Requirements

Identification and Authorization must be met by one of the following methods:

- a. Direct implementation in the user interface.

- b. For user interfaces on a computer: inheriting the Identification and Authorization from the computer operating system, either by the operating system limiting access to specific applications by user, or by the application itself having permissions based on the user logged into the computer.
- c. For remote interfaces: an implementation shared between the remote user interface server and the remote user interface client. For example, a requirement for PIV authentication may be met on a remote user interface by a PIV reader on a web browser client which sends the authentication information via HTTPS to the remote server.

3.4.5 Password-Based Authentication Requirements

3.4.5.1 Passwords for Software and Applications Running on Computers

All software and applications running on computers supporting password-based authentication must enforce the following requirements:

- a. Minimum password length of 12 characters
- b. Password must contain at least one uppercase character.
- c. Password must contain at least one lowercase character.
- d. Password must contain at least one numeric character.
- e. Password must contain at least one special character. The list of supported special characters must include at least 4 separate characters.
- f. Password must have a minimum lifetime of 24 hours.
- g. Password must have a maximum lifetime of 60 days. When passwords expire, prompt users to change passwords. Do not lock accounts due to expired passwords.
- h. Password must differ from previous five passwords, where differ is defined as changing at least 50 percent of the characters (where location is significant, a character may be reused if it is in a different position).
- i. Passwords must be cryptographically protected during storage and transmission.

3.4.5.2 Passwords for Controllers FULLY Supporting Accounts

All controllers FULLY supporting accounts and supporting password-based authentication must enforce the following requirements:

- a. Minimum password length of twelve (12) characters
- b. Password must contain at least one uppercase character.
- c. Password must contain at least one lowercase character.
- d. Password must contain at least one numeric character.

- e. Password must contain at least one special character. The list of supported special characters must include at least 4 separate characters.
- f. Password must have a maximum lifetime of sixty (60) days. When passwords expire, prompt users to change passwords. Do not lock accounts due to expired passwords.
- g. Password must differ from previous five (5) passwords, where differ is defined as changing at least fifty percent of the characters.
- h. Passwords must be cryptographically protected during storage and transmission.

3.4.5.3 Passwords for Remote Interfaces

Passwords for connecting to a Remote User Interface supporting password-based authentication must enforce the following requirements:

- a. Minimum password length of twelve (12) characters
- b. Password must contain at least one uppercase character.
- c. Password must contain at least one lowercase character.
- d. Password must contain at least one numeric character.
- e. Password must contain at least one special character. The list of supported special characters must include at least 4 separate characters.
- f. Password must have a maximum lifetime of 60 days. When passwords expire, prompt users to change passwords. Do not lock accounts due to expired passwords.
- g. Password must differ from previous five passwords, where differ is defined as changing at least 50 percent of the characters (where location is significant, a character may be reused if it is in a different position).
- h. Passwords must be cryptographically protected during storage and transmission.

3.4.5.4 Passwords for Devices Minimally Supporting Accounts

Devices MINIMALLY supporting accounts must support passwords with a minimum length of four characters.

3.4.5.5 Password Configuration and Reporting

For all devices with a password, coordinate the changing of passwords with the project site following testing of the system but prior to turnover to the Government. Coordinate with Password Point of Contact to determine appropriate project site personnel to complete password changes. Accompany identified personnel to each device with a password and instruct personnel on the process of changing password. Record the time, date and personnel present when each device's password is changed and submit a Password Change Summary Report documenting this information.

Provide the Password Summary Report electronically in both PDF and Microsoft Excel.

3.4.6 Authenticator Feedback

{For Government Reference Only: This subpart relates to IA-6; CCI-000206}

Devices must never show authentication information, including passwords, on a display. Devices that momentarily display a character as it is entered, and then obscure the character, are acceptable. For devices that have STIGs or SRGs related to obscuring of authenticator feedback (CCI-000206), comply with the requirements of those STIGS/SRGs.

3.5 CYBERSECURITY AUDITING

Where an auditing requirement exists for email notification, notify via email the application administrator and Information System Security Officer (ISSO) of the event. Coordinate with the Email Address Point of Contact for email addresses. If outgoing email is not available to the system, configure the system for these notifications for future support of outgoing email.

3.5.1 Audit Events, Content of Audit Records, and Audit Generation

{For Government Reference Only: This subpart (and its subparts) relates to AU-2(a), AU-2(c), AU-2(d), AU-3, AU-10, AU-12, AU-13(3), AU-14(b), AU-14(1), AU-14(2), AU-14(3), CM-5(1), SC-7 (9); CCI-000123, CCI-001571, CCI-000125, CCI-001485, CCI-000130, CCI-000131, CCI-000132, CCI-001230, CCI-000133, CCI-000134, CCI-001487, CCI-000166, CCI-001899, CCI-000169, CCI-001459, CCI-000171, CCI-000172, CCI-001910, CCI-001914, CCI-001919, CCI-001464, CCI-001462, CCI-001920, CCI-001814, CCI-002400. }

For devices that have STIG/SRGs related to audit events, content of audit records or audit generation, comply with the requirements of those STIG/SRGs.

If auditing requirements can be met using existing control system alarm or event capabilities, those existing capabilities may be used to meet these requirements.

3.5.1.1 Computers

For each computer, provide the capability to select audited events and the content of audit logs. Configure computers to audit the indicated events, and to record the indicated information for each auditable event

3.5.1.1.1 Audited Events

Configure each computer to audit the following events:

- a. Successful and unsuccessful attempts to access, modify, or delete privileges, security objects, security levels, or categories of information (e.g. classification levels)
- b. Successful and unsuccessful logon attempts
- c. Successful logouts

- d. Privileged activities or other system level access
- e. Concurrent logons from different workstations
- f. Successful and unsuccessful accesses to objects
- g. All program initiations
- h. All direct access to the information system
- i. All account creations, modifications, disabling, and terminations.
- j. All kernel module load, unload, and restart

3.5.1.1.2 Audit Event Information To Record

Configure each computer to record, for each auditable event, the following information (where applicable to the event):

- a. What type of event occurred
- b. When the event occurred
- c. Where the event occurred
- d. The source of the event
- e. The outcome of the event
- f. The identity of any individuals or subjects associated with the event

3.5.1.2 For HVAC Control System Controllers

3.5.1.2.1 HVAC Control System Controllers FULLY Supporting User Accounts

For each controller which FULLY supports accounts, provide the capability to select audited events and the content of audit logs. Configure controllers to audit the indicated events, and to record the indicated information for each auditable event.

3.5.1.2.1.1 Audited Events

Configure each controller to audit the following events:

- a. Successful and unsuccessful logon attempts to the controller
- b. Successful logouts
- c. All account creations, modifications, disabling, and terminations.
- d. All controller shutdown and startup

3.5.1.2.1.2 Audit Event Information To Record

Configure each controller to record, for each auditable event, the following information (where applicable to the event):

- a. what type of event occurred

- b. when the event occurred
- c. the identity of any individuals or subjects associated with the event

3.5.1.2.2 Other HVAC Control System Controllers

There are no requirements to perform auditing at HVAC field controllers that do not FULLY support accounts.

3.5.1.3 Default Requirements for Control System Controllers

For control system controllers where Audit Events, Content of Audit Records, and Audit Generation are not otherwise indicated in this Section:

3.5.1.3.1 Controllers Which FULLY Support Accounts

For each controller which FULLY supports accounts, provide the capability to select audited events and the content of audit logs. Configure controllers to audit the indicated events, and to record the indicated information for each auditable event.

3.5.1.3.1.1 Audited Events

Configure each controller to audit the following events:

- a. Successful and unsuccessful attempts to access, modify, or delete privileges, security objects, security levels, or categories of information (e.g. classification levels)
- b. Successful and unsuccessful logon attempts
- c. Successful logouts
- d. Concurrent logons from different workstations
- e. All account creations, modifications, disabling, and terminations.
- f. All kernel module load, unload, and restart

3.5.1.3.1.2 Audit Event Information To Record

Configure each controller to record, for each auditable event, the following information (where applicable to the event):

- a. what type of event occurred
- b. when the event occurred
- c. where the event occurred
- d. the source of the event
- e. the outcome of the event
- f. the identity of any individuals or subjects associated with the event

3.5.1.3.2 Controllers Which Do Not FULLY Support Accounts

For each controller which does not FULLY support accounts configure the controller to audit all controller shutdown and startup events and to record for each event the type of event and when the event occurred.

3.5.2 Audit Time Stamps

{For Government Reference Only: This subpart (and its subparts) relates to AU-8; CCI-000159, CCI-001889, CCI-001890.}

Any device (computer or controller) generating audit records must have an internal clock capable of providing time with a resolution of one second. Clocks must not drift more than 10 seconds per day. Configure the system so that each device (computer or controller) generating audit records maintains accurate time to within 1 second. Note that if the control system specifications include requirement for clocks, the most stringent requirement applies.

3.5.3 Auditing Front End Software

If there is no existing auditing front end software or the software is not compatible with the provided control systems, provide Auditing Front End Software with audit log import and upload, export, notification, and analysis functionality. The Auditing Front End Software may be provided as a component of the control system front end or as a separate software package, and a single package may serve multiple control systems provided under the same projects if they are sharing a cybersecurity authorization.

When the Auditing Front End Software is neither existing nor installed under the requirements of another Section, furnish the Auditing Front End Software media and license for subsequent Government installation. Submit copies of Auditing Front End Software if this function is not part of the software provided with the control system to meet requirements of other Sections.

3.5.3.1 Import and Upload Requirements

Auditing Front End Software must be capable of importing audit logs from the Device Audit Record Upload Software and of uploading audit logs over the network from all control system devices supporting network upload of audit logs.

3.5.3.2 Export Requirements

Auditing Front End Software must be capable of exporting to a file format supported by Microsoft Excel.

3.5.4 Audit Storage Capacity and Audit Upload

{For Government Reference Only: This subpart (and its subparts) relates to AU-4; CCI-001848, CCI-001849}

The creation of audit records must never interfere with normal device operation. Devices must cease collection of auditing information if required to maintain normal operation.

- a. For devices that have STIG/SRGs related to audit storage capacity (CCI-001848 or CCI-001849) comply with the requirements of those STIG/SRGs.
- b. For controllers capable of generating audit records, provide 60 days worth of secure local storage, assuming 10 auditable events per day.
- c. For computers, provide storage for at least 120 days of audit records.

3.5.4.1 Device Audit Record Upload Software

For each device (computer or controller) required to audit events and for which audit logs cannot be uploaded over the network by the Auditing Front End Software, provide and license to the Government software implementing a secure mechanism of uploading audit records from the device and exporting them to the Auditing Front End Software. Where different devices use different software, provide software of each type required to upload audit logs from all devices.

When Device Audit Record Upload Software is capable of uploading audit logs over the network, install Device Audit Record Upload Software on the same computer as the Auditing Front End Software. Submit copies of device audit record upload software if this function is not part of the software provided with the control system to meet requirements of other Sections. If there are no devices requiring this software, provide a document stating this in lieu of this submittal.

3.5.5 Response to Audit Processing Failures

{For Government Reference Only: This subpart (and its subparts) relates to AU-5; CCI-000139, CCI-000140, CCI-001490.}

In the case of a failure in the auditing system, computers associated with auditing must provide email notification. In case of an audit failure, if possible, continue to collect audit records by overwriting existing audit records.

3.6 REQUIREMENTS FOR LEAST FUNCTIONALITY

{For Government Reference Only: This subpart (and its subparts), along with the network communication report submittal specified elsewhere in this section, relates to CM-6(a), CM-6(c), CM-7, CM-7(1)(b), SC-41; CCI-000363, CCI-000364, CCI-000365, CCI-001588, CCI-001755, CCI-000381, CCI-000380, CCI-000382, CCI-001761, CCI-001762, CCI-002544, CCI-002545, CCI-002546. }

For devices that have a STIG or SRG related to Requirements for Least Functionality (such as configuration settings and port and device I/O access for least functionality), install and configure the device in accordance with that STIG or SRGs.

3.6.1 Device Capabilities

For HVAC Control Systems: Do not provide devices with remote user interfaces or with full user interfaces where one was not required. Do

not use a networked sensor or actuator where a non-networked sensor or actuator would suffice.

For Other Control Systems: Do not provide devices with remote user interfaces or with full user interfaces where one was not required. Do not use a networked sensor or actuator where a non-networked sensor or actuator would suffice.

3.6.2 Software

For software that has a STIG or SRG related to Requirements for Least Functionality (such as configuration settings and port access for least functionality), install and configure the software in accordance with that STIG or SRG.

3.7 SYSTEM AND COMMUNICATION PROTECTION

3.7.1 Collaborative Computing

{For Government Reference Only: This subpart relates to SC-15(a), SC-15(b); CCI-001150, CCI-001152.}

Without explicit approval from the project site, control systems must not use collaborative computing technologies.

3.7.2 Denial of Service Protection

{For Government Reference Only: This subpart relates to SC-5, SC-39, SC-7(a); CCI-001093, CCI-002385, CCI-002386, CCI-002430, CCI-001097. }

To the greatest extent practical, implement control logic without reliance on the network. Except when required to meet the requirements of the control system Section (where the requirement can only be met using computer hardware), do not implement control logic in computers.

3.7.2.1 Default Requirements for MODERATE Impact Control Systems

Except for networked input and outputs on input-output buses specifically designed to provide high reliability or redundancy, sensors and actuators must not rely on the network to exchange data with the controller executing the sequence of operation which uses the sensor value or determines the actuator command.

Sensor values required by multiple devices may be shared over the network provided they are connected to a controller requiring the value for execution of the sequence and that controller shares the value on the network.

3.8 SAFE MODE AND FAIL SAFE OPERATION

{For Government Reference Only: This subpart (and its subparts) relates to CP-12, SI-10(3), SI-17; CCI-002855, CCI-002856, CCI-002857, CCI-002754, CCI-002773, CCI-002774, CCI-002775}

For all control system components with an applicable STIG or SRG, configure the component in accordance with all applicable STIGs and SRGs.

3.9 SYSTEM MAINTENANCE TOOL SOFTWARE

{For Government Reference Only: This subpart (and its subparts) relates to MA-3; CCI-000865.}

Submit and license to the Government all software required to operate, maintain and modify the control system such the Government or their agents are able to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on the Contractor, Vendor or Manufacturer. Submit hard copies of user manuals for each software with the software submittal.

For software provided and licensed to the Government under the requirements of another Section, submit a statement indicating the Section and Submittal under which the software was provided. For software provided to meet the requirements of this Section and not provided and licensed under another Section, submit software and software user manuals on DVD or CD as a Technical Data Package and submit 3 hard copies of the software user manual for each piece of software.

3.10 DEVICE POWER

{For Government Reference Only: This subpart (and its subparts) relates to PE-11, PE-11(1); CCI-002955, CCI-000961. }

For LOW Impact Systems: Provide emergency power in accordance with the control system and equipment specification Sections in Division 23

3.11 VULNERABILITY SCANNING

{For Government Reference Only: This subpart (and its subparts) relates to RA-5 RA-5(a),RA-5(b),RA-5(c),RA-5(d); CCI-001054, CCI-001055, CCI-000156, CCI-001641, CCI-001643, CCI-001057, CCI-001058, CCI-001059. }

All IP devices must be scannable, such that the device can be scanned by industry standard IP network scanning utilities without harm to the device, application, or functionality.

3.11.1 Computers and Software Running on Computers

Computers and applications running on computers must meet relevant vulnerability scanning STIGs/SRGs and respond to approved DoD vulnerability scanning tools.

3.11.2 Controllers

Provide controllers that are scannable by standard control system discovery tools or control system browsers and return meaningful status information including the network inputs and outputs for the controller. This information must contain sufficient detail to detect vulnerabilities or exploits of the controller.

Provide all software needed to scan the control system as the Control

System Scanning Tools submittal. If the software required to scan the system is already installed at the project site or is provided under a separate section instead provide a statement indicating this.

3.12 FIPS 201-2 REQUIREMENT

{For Government Reference Only: This subpart (and its subparts) relates to SA-4 (10); CCI-003116}

Devices in the following systems which implement PIV must be on the NIST FIPS 201-2 approved product list (<https://www.idmanagement.gov/approved-products-list/>): NONE.

3.13 SYSTEM AND INTEGRATION INTEGRITY

3.13.1 Malicious Code Protection

{For Government Reference Only: This subpart (and its subparts) relates to SI-3(c); CCI-001241, CCI-002623}

For all computers installed under this project, provide malware protection software media, provide licenses, and install and configure malware protection software as indicated. Coordinate with the Government Computer Access Point of Contact as required.

- a. Provide malware protection software licenses.
- b. Provide malware protection software media.
- c. Install and configure malware protection software in accordance with the relevant STIGs.

3.14 CONTROL SYSTEM CYBERSECURITY TESTING

3.14.1 Control System Cybersecurity Testing Procedures

Prepare Control System Cybersecurity Testing Procedures explaining step-by-step, the actions and expected results that will demonstrate that the control system meets the requirements of this Section.

Submit 4 copies of the Control System Cybersecurity Testing Procedures. The Control System Cybersecurity Testing Procedures may be submitted as a Technical Data Package.

3.14.2 Control System Cybersecurity Testing Execution

Using the Control System Cybersecurity Testing Procedures verify that the control system meets the requirements of this Section. UNLESS GOVERNMENT WITNESSING OF A TEST IS SPECIFICALLY WAIVED BY THE GOVERNMENT, PERFORM ALL TESTS WITH A GOVERNMENT WITNESS. If testing reveals deficiencies in the system, correct the deficiency and retest until successful.

3.14.3 Control System Cybersecurity Testing Report

Prepare and submit a Control System Cybersecurity Testing Report documenting all tests performed and their results. Include all tests in

the Control System Cybersecurity Testing Procedures and any additional tests performed during testing. Document test failures and repairs conducted with the test results.

Submit four copies of the Control System Cybersecurity Testing Report. The Control System Cybersecurity Testing Report may be submitted as a Technical Data Package.

3.15 FIELD QUALITY CONTROL, CYBERSECURITY VALIDATION SUPPORT

In addition to testing and testing support required by other Sections, provide a minimum of 24

hours of technical support for cybersecurity testing of control systems to support the DoD Risk Management Framework process Cybersecurity assessment of the control system. This support is independent of (and in addition to) the Control System Cybersecurity Testing specified in this section.

3.16 CYBERSECURITY TRAINING

Provide eight hours of classroom and hands-on training for six Government personnel on the cybersecurity operation and maintenance of the control system provided. This training is in addition to and must be coordinated with control system training specified in other Sections.

The Government will provide the training location. Training must cover, at a minimum: (a) applying software and firmware updates, (b) user account creation, modification and deletion, (c) audit log upload procedures and (d) identification of privileged user interfaces and system impact of those interfaces. Training session must include a question and answer period during which government staff questions about cybersecurity aspects of the control system are answered.

-- End of Section --

SECTION 25 05 11.02

CYBERSECURITY FOR LOW IMPACT LIGHTING CONTROL SYSTEMS
05/21, CHG 1: 08/23

PART 1 GENERAL

Many subparts in this Section contain text in curly braces ("{" and "}") indicating which cybersecurity control and control correlation identifier (CCI) the requirements of the subpart relate to. The text inside these curly braces is for Government reference only and enables coordination of the requirements of this Section with the RMF process throughout the design and construction process. Text in curly braces are not contractor requirements.

This Section refers to Security Requirements Guide (SRGs) and Security Technical Implementation Guide (STIGs). STIGs and SRGs are available online at the Information Assurance Support Environment (IASE) website at <https://public.cyber.mil/stigs/downloads/> and an SRG/STIG Applicability Guide and Collection Tool is available at <https://public.cyber.mil/stigs/SCAP/>. Not all control system components have applicable STIGs or SRGs. The "Control Systems SRG" does not apply to work performed under this Section; all requirements within this section to apply applicable SRGs DO NOT include the "Control Systems SRG".

1.1 CONTROL SYSTEM APPLICABILITY

There are multiple versions of this Section associated with this project. Different versions have requirements applicable to different control systems. This specific Section applies only to the following control systems: Lighting Control System.

1.2 RELATED REQUIREMENTS

This section does not contain sufficient requirements to procure a control system and must be used in conjunction with other Sections which specify control systems. This Section adds cybersecurity requirements to the control systems specified in other Sections, and as these requirements are conditioned on the control system being provided, there may be requirements in this Section that will not apply to this project. All Sections containing facility-related control systems or control system components are related to the requirements of this Section. Review all specification sections to determine related requirements.

In cases where a requirement is specified in both this Section and in another Section, the more stringent requirement must be met. In cases where a requirement in this Section conflicts with the requirements of another Section such that both requirements cannot be met at the same time, request direction from the Contracting Officer Representative to determine which requirement applies to the project.

1.3 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST FIPS 201-2 (2013) Personal Identity Verification
(PIV) of Federal Employees and Contractors

U.S. DEPARTMENT OF DEFENSE (DOD)

DTM 08-060 (2008) Policy on Use of Department of
Defense (DoD) Information Systems -
Standard Consent Banner and User Agreement

1.4 DEFINITIONS

1.4.1 Administrator Account

An administrator account is an account with full permissions to a device, application, or operating system, including the ability to create and modify other user accounts.

Note that the operating system Administrator Account may be different than Administrator Accounts for applications hosted on that operating system. Also, most controllers will not have any support for accounts and will therefore not have an 'Administrator Account'.

1.4.2 Computer

A computer is one of the following:

- a. a device running a non-embedded desktop or server version of Microsoft Windows
- b. a device running a non-embedded version of MacOS
- c. a device running a non-embedded version of Linux
- d. a device running a version or derivative of the Android Operating System, where Android is considered separate from Linux
- e. a device running a version of Apple iOS

Unless otherwise indicated or clear from context use of the word "device" in this Section includes computers.

1.4.3 Controller

A device other than a computer or Ethernet switch.

1.4.4 Mission Space

A device or media is in mission space if physical access to the device or

media is controlled by the organization served by the device. For example, a VAV box controller in a suspended ceiling is in mission space if the VAV box serves that room; an electrical switchgear in an electrical room or an AHU in a mechanical room or on a rooftop may still be considered to be in mission space if the organization (mission) served by that switchgear or AHU controls access to the electrical room, mechanical room or rooftop.

1.4.5 Network

A network is a group of two or more devices that can communicate using a network protocol. Network protocols must provide a method for addressing devices on the network; a communication method that does not provide an addressing scheme is not a networked form of communication. Devices that communicate using a method of communication that does not support device addressing are not using a network.

1.4.6 Network Connected

A component is network connected (or "connected to a network") only when the device has a network transceiver which is directly connected to the network and implements the network protocol. A device lacking a network transceiver (and accompanying protocol implementation) can never be considered network connected. Note that (unlike many IT definitions of "Network Connected") a device connected to a non-IP network is still considered network connected (an IP connection or IP address is not required for a device to be network connected).

1.4.6.1 Wireless Network Connected

Any device that supports wireless network communication is network connected to a wireless network, regardless of whether the device is communicating using wireless. Unless physically disabled, devices with wireless transceivers support wireless, it is not sufficient to disable the wireless in software.

1.4.7 Network Media

The thing that provides the communication channel between the devices on a network. Typically wire, but might include wireless, fiber optic, or even power line (some network protocols allow sending network signals over power wiring).

1.4.8 User Account Support Levels

The support for user accounts is categorized in this Section as one of three levels:

1.4.8.1 FULLY Supported

Device supports configurable individual accounts. Accounts can be created, deleted, modified, etc. Privileges can be assigned to accounts. These devices support user-based (as opposed to role-based) authentication.

1.4.8.2 MINIMALLY Supported

Device supports a small, fixed number of accounts (perhaps only one). Accounts cannot be modified. A device with only a "User" and an

"Administrator" account would fit this category. Similarly, a device with two PINs for logon - one for restricted and one for unrestricted rights would fit here (in other words, the accounts do not have to be the traditional "username and password" structure). These devices typically only support role-based authentication.

Examples of devices which MINIMALLY support accounts are a) a variable frequency drive with a single account which requires a PIN for access to configuration; and b) a room lighting control touchpad interface that has a single account.

1.4.8.3 NOT Supported

Device does not support any Access Enforcement therefore the whole concept of "account" is meaningless.

1.4.9 Manual Local Input

Manual Local Inputs are system analog or binary inputs that are adjustable by a person but are, by intrinsic hardware design, very limited in potential capabilities. Manual Local Inputs do not have touch screens or full keyboards, but may have a few buttons or dials to allow input. Manual Local Inputs do not have full graphic screens or dot-matrix displays, but may have simple lights (LEDs) or 7-segment displays. Manual Local Inputs do not have any sort of menu structure, each button has a single well-defined function.

Examples of Manual Local Inputs are H-O-A switches, simple thermostats, and disconnect switches.

1.4.10 Card Reader

A card reader is an input/output device whose primary function is to assist in two-factor authentication. A card reader must have an interface to read data from a card and may be able to write data to a card. A card reader may have a means (such as buttons, keypad, touchscreen, etc.) for a user to input a PIN or password, as well as a limited display.

1.4.11 User Interface

A User Interface (UI) is something other than a Manual Local Input or Card Reader that allows a person to interact with the system or device. Note that while a Card Reader is not by itself a User Interface, a User Interface may contain a Card Reader in order for it to authenticate its user. Within control systems, there are a wide range of User Interfaces.

Two important distinctions are 1) whether the user interface is Local or Remote, and 2) the effective capabilities of the User Interface to alter data, which is the "privilege" of the user interface (where effective privilege available to a specific user at a specific user interface is the combination of the greatest privilege offered by the user interface and the specific account the user is logged into).

1.4.11.1 Local User Interface

A Local User Interface is a user interface where the physical hardware the user interacts with (keyboard, buttons, display, etc.) is physically part of the device being affected. All of the relevant characteristics of the

user interface are embodied within a single device.

Note that a Local UI may be able to access data in a different device, Local versus Remote in this context refers to the user interface itself; the capability to access data in a different device is covered under "Full User Interface".

1.4.11.2 Remote User Interface

A Remote User Interface implements a Client/Server model where the physical hardware the user interacts with (Client) is physically distinct from the device being affected (Server). Most or all of the security and functionality characteristics of the user interface are defined by the Server, not the Client. The Client and Server communicate via a network connection. A common example of a remote user interface is a web-based interface where the browser (client) is generally on different hardware than the web server (server). A Remote UI remains a Remote UI even if the user happens to be at a Client on the same hardware as the Server. What is important is that a) the Client may be on different hardware than the Server and b) the majority of the security and functional characteristics of the interface are defined at the Server.

Note that this definition of "remote" is consistent with that generally used in the control industry but is not aligned with the NIST 800-53 definition of "Remote", which refers to "outside the system". The term "Remote" here better aligns with the NIST 800-53 definition of "Network (remote from within the system) Access".

1.4.11.3 Types of User Interface (by capability)

User interfaces are also categorized by their capabilities as being Read Only, Limited, or Full.

1.4.11.3.1 Read-Only User Interface

A Read Only User Interface (also referred to as a View-Only User Interface) is a user interface that only allows for reading data, it does not allow (have the capability to) modify data. A Read Only User Interface may be either Local or Remote. A User Interface that is configured to be Read Only (by some other means than the interface itself, such as using configuration software on a laptop) is a Read-Only Interface. Note a Read Only User Interface may have buttons (or touch screen, etc.) allowing the user to navigate through the presentation of data.

Examples of a Read Only User Interfaces are a) a publicly viewable "energy dashboard" showing weather data and energy usage within a building and b) digital wayfinding signage.

1.4.11.3.2 Limited User Interface

A Limited User Interface is a user interface that - by design - can only alter information local to the user interface. Note that the determination of "alter" includes only direct interactions, it explicitly excludes interactions that might occur as secondary effects. For example, an interface changing the flow setpoint in a pump controller is a direct interaction, the subsequent change in flow (as well as any subsequent downstream changes in valve position) are not direct interactions.

Two examples of LIMITED UIs are: a) a variable speed drive has a Limited Local User Interface which allows the user to change properties within the drive, but does not allow affecting things outside the drive; and b) a typical home WiFi Router has a Limited Remote User Interface which allows configuration of the Router, but does not allow direct interaction with other devices.

1.4.11.3.3 Full User Interface

A Full User Interface can alter information in devices outside the device with the user interface. For example, a typical Local Display Panel is a Full Local User Interface while a browser-based front end is a Full Remote User Interface.

1.4.11.3.4 View-Only User Interface

See Read-Only User Interface

1.4.11.4 Other User Interface Terminology

In addition to defining whether a user interface is a Hardware Limited, Read-Only, Limited or Full, and whether it is Local or Remote, user interfaces are classified by whether they are writable or privileged.

1.4.11.4.1 Writable User Interface

Any User Interface that is not Read-Only is Writable. (Limited User Interfaces and Full User Interfaces are both writable user interfaces (as they are capable of changing a value)).

1.4.11.4.2 Privileged User Interface

A Privileged UI is a UI that has sufficient capabilities or functionality that it requires specific cybersecurity measures to be put in place to limit its unauthorized use. Ultimately, whether a specific user interface is considered a Privileged User Interface must be determined by usage. Unless otherwise specified, user interfaces can be determined to be privileged or not using the following:

- a. Read-Only User Interfaces are not privileged user interfaces.
- b. Full User Interfaces are privileged user interfaces.
- c. User interfaces that allow for configuration of auditing or allows for modification or deletion of audit logs are privileged user interface.
- d. User interfaces that allow for reprogramming a network connected device is a privileged user interface.
- e. Except as specified above, a Limited User Interface must be determined to be privileged or not based on the specific capabilities and use case of the user interface. In general however, user interfaces that do not offer significant capabilities above and beyond those available at that location via other means (e.g. such as a disconnect switch, breaker, or hand-off-auto switch, or physical attack) are not privileged.

1.4.12 Wireless Network

Any network that communicates without using wires or fiber optics as the communication media. Wireless networks include: WiFi, Bluetooth, ZigBee, cellular, satellite, 900 MHz radio, 2.4 GHz, free space optical, point-to-point laser, and IR.

1.4.13 Wired Broadcast Network

Wired Broadcast Networks are any network, such as powerline carrier networks and modem (wired telephony), that use wire-based technologies where there is not a clearly defined boundary for signal propagation.

1.5 ADMINISTRATIVE REQUIREMENTS

1.5.1 Points of Contact

Coordinate with the following Points of Contact as indicated in this Section and as required. Not all projects will require coordination with all Points of Contact. When coordination is required and no Point of Contact is indicated, coordinate with The Contracting Office Representative (COR).

- a. Government Computer Access Point of Contact: The Contracting Office Representative (COR)
- b. HTTPS Certificate Point of Contact: The Contracting Office Representative (COR)
- c. Email Address Point of Contact: The Contracting Office Representative (COR)
- d. Password Point of Contact: The Contracting Office Representative (COR)
- e. Mobile Code Point of Contact: The Contracting Office Representative (COR)
- f. PKI Infrastructure Point of Contact: The Contracting Office Representative (COR)

1.5.2 Coordination

Coordinate the execution of this Section with the execution of all other Sections related to control systems as indicated in the paragraph RELATED REQUIREMENTS. Items that must be considered when coordinating project efforts include but are not limited to:

- a. If requesting permission for wireless or wired broadcast communication, the Wireless and Wired Broadcast Communication Request submittal must be approved prior to control system device selection and installation.
- b. If requesting permission for alternate account lock permissions, the Device Account Lock Exception Request must be approved prior to control system device selection and installation.
- c. If requesting permission for the use of a device with multiple physical connections to IP networks, the Multiple IP Connection Device

Request must be approved prior to control system device selection and installation.

- d. Wireless testing may be required as part of the control system testing. See requirements for the Wireless Communication Test Report submittal.
- e. If the Device Audit Record Upload Software is to be installed on a computer not being provided as part of the control system, coordination is required to identify the computer on which to install the software.
- f. The Cybersecurity Interconnection Schedule must be coordinated with other work that will be interconnected to, and interconnections must be approved by the Government before relying on them for system functionality.
- g. Cybersecurity testing support must be coordinated across control systems and with the Government cybersecurity testing schedule.
- h. Passwords must be coordinated with the indicated contact for the project site.
- i. If applicable, HTTPS web server certificates must be obtained from the indicated HTTPS Certificate Point of Contact.
- j. Contractor Computer Cybersecurity Compliance Statements must be provided for each contractor using contractor owned computers.

1.6 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Device Account Lock Exception Request; G

Contractor Computer Cybersecurity Compliance Statements; G

Contractor Temporary Network Cybersecurity Compliance Statements; G

Proposed STIG and SRG Applicability Report; G

SD-02 Shop Drawings

Cybersecurity Riser Diagram; G

SD-03 Product Data

Control System Cybersecurity Documentation; G

SD-06 Test Reports

Wireless Communication Test Report; G

Control System Cybersecurity Testing Procedures; G

Control System Cybersecurity Testing Report; G

SD-07 Certificates

Software Licenses; G

SD-11 Closeout Submittals

Password Change Summary Report; G

Enclosure Keys; G

Software and Configuration Backups; G

Auditing Front End Software; G

Device Audit Record Upload Software; G

System Maintenance Tool Software; G

Control System Scanning Tools; G

STIG, SRG and Vendor Guide Compliance Result Report; G

Control System Inventory Report; G

1.7 QUALITY CONTROL

1.7.1 Qualifications

For the Lighting control system:

For the position listed below resumes should be submitted to the Government within 14 days after notice to proceed. All certifications must be in effect prior to being hired.

These positions may serve across the contract and provide on-site support as required..

1.7.1.1 Cybersecurity Subject Matter Expert

The individual will over see all work within these specification. This position requires that the individual currently meets Information Assurance Management Level II Certification in accordance with DODD 8140 Cybersecurity Workforce Management and DODI 8570 Information Workforce Improvement Program.

Individuals for this position should have experience securing DoD Systems and with Risk Management Framework

1.8 CYBERSECURITY DOCUMENTATION

{For Government Reference Only: This subpart (and its subparts) relates to PL-7; CCI-003071}

1.8.1 Proposed STIG and SRG Applicability Report

For each model of network connected or network infrastructure device, use the DISA SRG/STIG Applicability Guide and Collection Tool (available at <https://public.cyber.mil/stigs/SCAP/>) to identify applicable STIGs or SRGs and provide a report indicating applicable STIGs and SRGs for each model.

1.8.2 Control System Inventory Report

{For Government Reference Only: This subpart (and its subparts) relates to CM-8(a), SI-17, IA-3; CCI-000389, CCI-000392, CCI-000398, CCI-002773, CCI-002774, CCI-002775, CCI-000777, CCI-000778, CCI-001958}

Provide a Control System Inventory report using the Inventory Spreadsheet listed under this Section at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1> documenting all devices, including networked devices, network infrastructure devices, non-networked devices, input devices (e.g. sensors) and output devices (e.g. actuators). For each device provide all applicable information for which there is a field on the spreadsheet in accordance with the instructions on the spreadsheet.

In addition to the requirements of Section 01 33 00 SUBMITTAL PROCEDURES, provide the Control System Inventory Report as an editable Microsoft Excel file.

1.8.3 Software and Configuration Backups

{For Government Reference Only: This subpart (and its subparts) relates to CP-10; CCI-000550, CCI-000551, CCI-000552}

For each computer on which software is installed under this project, provide a recovery image of the final as-built computer. This image must allow for bare-metal restore such that restoration of the image is sufficient to restore system operation to the imaged state without the need for re-installation of software. If additional user permissions are required to meet this requirement, coordinate the creation of the image with the identified Government Computer Access Point of Contact.

For all ethernet switches provide a backup of the switch configuration. For all controllers, provide a backup of the controller configuration and the source code for all loaded application programs (all software that is not common to every controller of the same manufacturer and model).

If any or all of these are provided under another Section, provide documentation indicating this and referencing those submittals.

1.8.4 Cybersecurity Riser Diagram

{For Government Reference Only: This subpart (and its subparts) relates to PL-2(a), PL-8; CCI-003051, CCI-003053, CCI-003072, CCI-003073, CCI-003075}

Provide a cybersecurity riser diagram of the complete control system including all network and device hardware. If the control system specifications require a riser diagram submittal, provide a copy of that submittal as the cybersecurity riser diagram. Otherwise, provide a riser diagram in one-line format.

1.8.5 STIG, SRG and Vendor Guide Compliance Result Report

For every component (device or software) with an applicable STIG or SRG in the Proposed STIG and SRG Applicability Report, provide a result report documenting compliance with the STIG or SRG requirements. For components which are scannable by the SCAP (security content automation protocol) tool (available online at <https://public.cyber.mil/stigs/scap>), provide the SCAP report and raw scan results.

For every component (device or software) with manufacturer provided cybersecurity documentation, procedure, or method for secure configuration or installation, provide a report documenting how the component was configured and any deviation from the manufacturer instructions.

1.8.6 Control System Cybersecurity Documentation

{For Government Reference Only: This subpart (and its subparts) relates to SA-5(a), SA-5(b), SA-5(c), SA-22(b); CCIs: CCI-003124, CCI-003125, CCI-003126, CCI-003127, CCI-003128, CCI-003129, CCI-003130, CCI-003131, CCI-003374}

Provide a Control System Cybersecurity Documentation submittal containing the indicated information for each device and software application.

1.8.6.1 Software Applications

For all software applications running on computers provide:

- a. administrator documentation that describes secure configuration of the software {For Government Reference Only: relates to CCI-003124}
- b. administrator documentation that describes secure installation of the software and software updates. {For Government Reference Only: relates to CCI-003125}
- c. administrator documentation that describes secure operation of the software {For Government Reference Only: relates to CCI-003124}
- d. administrator documentation that describes effective use and maintenance of security functions or mechanisms for the software {For Government Reference Only: relates to CCI-003127}
- e. administrator documentation that describes known vulnerabilities regarding configuration and use of administrative (i.e. privileged) functions for the software {For Government Reference Only: relates to

CCI-003128}

- f. user documentation that describes user-accessible security functions or mechanisms in the software and how to effectively use those security functions or mechanisms {For Government Reference Only: relates to CCI-003129}
- g. user documentation that describes methods for user interaction which enables individuals to use the software in a more secure manner {For Government Reference Only: relates to CCI-003130}
- h. user documentation that describes user responsibilities in maintaining the security of the software {For Government Reference Only: relates to CCI-003131}

1.8.6.2 For Lighting Control System Devices

1.8.6.2.1 Lighting Control System Devices FULLY Supporting User Accounts

For all Lighting Control System Devices which FULLY support user accounts, provide:

- a. Documentation that describes secure configuration of the device {For Government Reference Only: relates to CCI-003124}
- b. Documentation that describes secure operation of the device {For Government Reference Only: relates to CCI-003124}
- c. Documentation that describes effective use and maintenance of security functions or mechanisms for the device {For Government Reference Only: relates to CCI-003127}
- d. Documentation that describes known vulnerabilities regarding configuration and use of administrative (i.e. privileged) functions for the device {For Government Reference Only: relates to CCI-003128}
- e. Documentation that describes user-accessible security functions or mechanisms in the device and how to effectively use those security functions or mechanisms; or a specific indication that there are no user-accessible security functions or mechanisms in the device {For Government Reference Only: relates to CCI-003129}
- f. Documentation that describes methods for user interaction which enables individuals to use the device in a more secure manner {For Government Reference Only: relates to CCI-003130}

1.8.6.2.2 All Other Lighting Control System Devices

For all Lighting Control System Devices which do not FULLY support user accounts, provide:

- a. Documentation that describes secure configuration of the device; or a specific indication that there are no secure configuration steps that apply {For Government Reference Only: relates to CCI-003124}
- b. Documentation that describes effective use and maintenance of security functions or mechanisms for the device; or a specific indication that there are no security functions or mechanisms in the device {For Government Reference Only: relates to CCI-003127}

- c. For devices which include a user interface, documentation that describes methods for user interaction which enables individuals to use the device in a more secure manner {For Government Reference Only: relates to CCI-003130}

1.8.6.3 Default Requirements for Control System Devices

For control system devices where Control System Cybersecurity Documentation requirements are not otherwise indicated in this Section, provide:

- a. Documentation that describes secure configuration of the device {For Government Reference Only: relates to CCI-003124}
- b. Documentation that describes secure installation of the device {For Government Reference Only: relates to CCI-003125}
- c. Documentation that describes secure operation of the device {For Government Reference Only: relates to CCI-003124}
- d. Documentation that describes effective use and maintenance of security functions or mechanisms for the device {For Government Reference Only: relates to CCI-003127}
- e. Documentation that describes known vulnerabilities regarding configuration and use of administrative (i.e. privileged) functions for the device {For Government Reference Only: relates to CCI-003128}
- f. Documentation that describes user-accessible security functions or mechanisms in the device and how to effectively use those security functions or mechanisms {For Government Reference Only: relates to CCI-003129}
- g. Documentation that describes methods for user interaction which enables individuals to use the device in a more secure manner {For Government Reference Only: relates to CCI-003130}
- h. Documentation that describes user responsibilities in maintaining the security of the device {For Government Reference Only: relates to CCI-003131}
- i. Documentation of the published last date of support by the manufacturer or indication that a published date is not available. {For Government Reference Only: relates to CCI-003374}

1.9 SOFTWARE LICENSING

{For Government Reference Only: This subpart (and its subparts) relates to SI-2(a), SI-2(c), SI-7(14); CCI-001227, CCI-002605, CCI-002737}

For all software provided that has not already been licensed to the government or project site, provide a license to the Government for a period of no less than 5 years, and the license must also include the following software updates:

- a. Security and bug-fix patches issued by the software manufacturer.
- b. Security patches to address any vulnerability identified in the National Vulnerability Database at <http://nvd.nist.gov> with a Common Vulnerability Scoring System (CVSS) severity rating of MEDIUM or higher.

Provide a single Software Licenses submittal with documentation of the software licenses for all software provided

1.10 CYBERSECURITY DURING CONSTRUCTION

{For Government Reference Only: This subpart (and its subparts) relates to AC-18, SA-3; CCI-000258}

In addition to the control system cybersecurity requirements indicated in this section, meet following requirement throughout the construction process.

1.10.1 Contractor Computer Equipment

Contractor owned computers may be used for construction. Contractor computers connected to the control system, control system network, or a control system component at any point during construction must meet the following requirements:

1.10.1.1 Operating System

The operating system must be an operating system currently supported by the manufacturer of the operating system. The operating system must be current on security patches and operating system manufacturer required updates.

1.10.1.2 Anti-Malware Software

The computer must run anti-malware software from a reputable software manufacturer. Anti-malware software must be a version currently supported by the software manufacturer, must be current on all patches and updates, and must use the latest definitions file. Computers used on this project must be scanned using the installed software at least once per day.

1.10.1.3 Passwords and Passphrases

The passwords and passphrases for computers, applications, and web-based applications supporting passwords must be changed from their default values. Passwords must be a minimum of eight characters with a minimum of one uppercase letter, one lowercase letter, one number and one special character.

1.10.1.4 User-Based Authentication

Each user must have a unique account; sharing of a single account between multiple users is prohibited.

1.10.1.5 Demonstration of Compliance

The Government has the right to require demonstration of computer compliance with these requirements at any time during the project.

1.10.1.6 Contractor Computer Cybersecurity Compliance Statements

Provide a single submittal containing completed Contractor Computer Cybersecurity Compliance Statements for each company using contractor owned computers. Contractor Computer Cybersecurity Compliance Statements must use the template published at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1> Each Statement must be signed by a cybersecurity representative for the relevant company.

1.10.2 Temporary IP Networks

Temporary contractor-installed IP networks may be used during construction. When used, temporary contractor-installed IP networks connected to the control system, control system network, or a control system component at any point during construction must meet the following requirements:

1.10.2.1 Network Boundaries and Connections

The network must not extend outside the project site and must not connect to any IP network other than those specifically provided or furnished for this project. Any and all access to the network from outside the project site is prohibited.

1.10.3 Government Access to Network

Government personnel must be allowed to have complete and immediate access to the network at any time in order to verify compliance with this specification.

1.10.4 Temporary Wireless IP Networks

In addition to the other requirements on temporary IP networks, temporary wireless IP (WiFi) networks, when permitted, must not interfere with existing wireless networks, must use WPA2 security and must not broadcast the network name (SSID). Network names (SSID) for wireless networks must be changed from their default values.

1.10.5 Passwords and Passphrases

The passwords and passphrases for all network devices and network access must be changed from their default values. Passwords must be a minimum 8 characters with a minimum of one uppercase letter, one lowercase letter, one number and one special character.

1.10.6 Contractor Temporary Network Cybersecurity Compliance Statements

Provide a single submittal containing completed Contractor Temporary Network Cybersecurity Compliance Statements for each company implementing a temporary IP network. Contractor Temporary Network Cybersecurity Compliance Statements must use the template published at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1> Each Statement must be signed by a cybersecurity representative for the relevant company. If no temporary IP networks will be used, provide a single copy of the Statement indicating this.

1.11 CYBERSECURITY DURING WARRANTY PERIOD

All work performed on the control system after acceptance must be performed using Government Furnished Equipment or equipment specifically and individually approved by the Government.

PART 2 PRODUCTS

All products used on this project must meet the indicated requirements, but not all products specified here will be required by every project.

PART 3 EXECUTION

3.1 ACCESS CONTROL REQUIREMENTS

3.1.1 User Accounts

{For Government Reference Only: This subpart (and its subparts) relate to AC-2(a), AC-3, AC-6(1), AC-6(10), AC-6(2), AC-6(9), CM-11(2), and IA-2; CCI-002110, CCI-000213, CCI-001558, CCI-002221, CCI-002222, CCI-002223, CCI-002235, CCI-000039, CCI-001419, CCI-002234, CCI-001812, and CCI-000764. }

Any user interface supporting user accounts (either FULLY or MINIMALLY) must limit access according to specified limitations for each account. Install and configure any device having a STIG or SRG in accordance with that STIG or SRG.

All user interfaces FULLY supporting accounts must implement user-based authentication where each account is uniquely assigned to a specific user. User interfaces FULLY supporting accounts must implement at least three (3) levels of user account privilege including: 1) an account with read-only permissions 2) an account with full permissions including account creation and modification and 3) an account with greater permissions than read-only but without account creation and modification.

3.1.1.1 Computers

All computer operating systems must FULLY support user accounts and implement accounts for access. Each control system software application not supporting accounts and running on a computer must be installed such that use of the software is restricted by the computer operating system to specific users.

Applications running on computers must not require the user be logged in to a computer operating system administrator account for normal operation. It is permissible to require the computer operating system administrator account for initial application installation and configuration.

3.1.1.2 Controllers

For user interfaces provided by controllers, provide access control in accordance with the User Interface Requirements table for the applicable control system and user interface type.

a. For table entries of "NA": NA means Not Applicable, there are no

interfaces in this category.

- b. For table entries of "None Required": The user interface is not required to support user accounts.
- c. For table entries of "MINIMALLY": The user interface must at least MINIMALLY support user accounts.
- d. For table entries of "FULLY": The user interface must at FULLY support user accounts.
- e. For table entries of "KEY": The user interface must have physical security in the form of either a key lock on the interface itself or be furnished inside a locked enclosure. Where this is required for a read only interface, this lock must prevent viewing of data on the interface; for other interfaces, this lock must prevent using the interface to alter data.
- f. For table entries of "Physical Security": For Local FULL interfaces, the interface must be located inside mission space. For Local Limited (not FULL) interfaces, the user interface must either a) be located within mission space or b) be protected by physical security at least as good as the control devices (and equipment controlled by the control devices) affected by the interface. For purposes of this requirement, 'affected' includes controllers with data that can be directly altered by the interface, as well as mechanical and/or electrical equipment directly controlled by those controllers, but does not include other interactions.
- g. Entries of the form "X and Y" must meet both the requirement indicated for X and the requirement indicated for Y. For example, an entry of "MINIMALLY and Physical Security" indicates the user interface must both MINIMALLY support accounts and have physical security.
- h. Entries of the form "X or Y" must meet either the requirement indicated for X or the requirement indicated for Y.

3.1.1.2.1 Lighting Control Systems

User Interface Requirements for LOW Impact Lighting Control Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u>
Local Read Only (see note 1)	None Required
Local Limited, Non-privileged	None Required
Local Limited, Privileged	Physical Security
Local Full	MINIMALLY
Remote Read Only	None Required
Remote Limited, Non-Privileged	MINIMALLY

User Interface Requirements for LOW Impact Lighting Control Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u>
Remote Limited, Privileged AND Remote Full (see note 2)	FULLY
Notes: 1)Local Read Only User Interfaces are always Non-Privileged 2)Remote Full User Interfaces are always Privileged	

3.1.1.2.2 Default Requirements for Other Control Systems

For control system devices where User Interface Requirements are not otherwise indicated in this Section, use the Default User Interface Requirements tables.

Default User Interface Requirements for LOW Impact Control Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u>
Local Read Only (see note 1)	None Required
Local Limited, Non-privileged	None Required
Local Limited, Privileged	Physical Security
Local Full	FULLY
Remote Read Only	None Required
Remote Limited, Non-Privileged	MINIMALLY
Remote Limited, Privileged AND Remote Full (see note 2)	FULLY
Notes: 1)Local Read Only User Interfaces are always Non-Privileged 2)Remote Full User Interfaces are always Privileged	

3.1.2 Unsuccessful Logon Attempts

{For Government Reference Only: This subpart (and its subparts) relate to AC-7 (a), AC-7 (b); CCI-000043, CCI-000044, CCI-001423, CCI-002236, CCI-002237, CCI-002238}

Except for high availability user interfaces indicated as exempt, devices must meet the indicated requirements for handling unsuccessful logon attempts. If a device cannot meet these requirements, document device capabilities to protect from subsequent logon attempts and propose alternate protections in a Device Account Lock Exception Request submittal. Do not implement alternate protection measures in lieu of the

indicated requirements without explicit permission from the Government. If no Device Account Lock Exceptions are requested, provide a document stating that no approval is being requested as the Device Account Lock Exception Request.

3.1.2.1 Devices MINIMALLY Supporting Accounts

For LOW Impact Systems: Devices which MINIMALLY (but not FULLY) support accounts are not required to lock based on unsuccessful logon attempts.

3.1.2.2 Devices FULLY Supporting Accounts

Devices which FULLY support accounts must meet the following requirements.

- a. It must lock the user account when three unsuccessful logon attempts occur within a 15 minute interval.
- b. Once an account is locked, the account must stay locked until unlocked by an administrator. If the account being locked is the sole administrator account on the device, the account must stay locked for 1 hour and then automatically unlock.
- c. Once the indicated number of unsuccessful logon attempts occurs, delay further logon prompts by 5 seconds.

3.1.2.3 High Availability Interfaces Exempt from Unsuccessful Logon Attempts Requirements

There are no high availability interfaces which are exempt from unsuccessful logon attempts requirements.

3.1.3 System Use Notification

{For Government Reference Only: This subpart (and its subparts) relates to AC-8; CCI-000048, CCI-002247, CCI-002243, CCI-002244, CCI-002245, CCI-002246, CCI-000050, CCI-002248}

3.1.3.1 System Use Notification for Remote User Interfaces

Remote user interfaces must display a warning banner meeting the requirements of DTM 08-060 on screen.

3.1.3.2 System Use Notification for Local User Interfaces

Devices which are connected to a network and have a local user interface must display a warning banner meeting the requirements of DTM 08-060 on the user interface screen if capable of doing so and must have a permanently affixed label with an approved banner from DTM 08-060 if unable to display the warning banner on the screen. Where it is impractical (perhaps due to device size) to affix the label to the device, affix the label to the device enclosure.

Labels must be machine printed or engraved, plastic or metal, designed for permanent installation, must use a font no smaller than 14 point, and must provide a high contrast between font and background colors.

3.1.4 Permitted Actions Without Identification or Authentication

{For Government Reference Only: This subpart (and its subparts) relates to AC-14; CCI-000061, CCI-000232}

The control system must require identification and authentication before allowing any actions except read-only actions by a user acting from a user interface which MINIMALLY or FULLY supports accounts.

3.1.5 Enclosures

Prior to final acceptance of the system, lock all lockable enclosures. Submit an Enclosure Keys submittal with all copies of keys for all enclosures and a key inventory list documenting all keys. Label each key with the matching enclosure identifier.

3.2 USER IDENTIFICATION AND AUTHENTICATION

{For Government Reference Only: This subpart (and its subparts) relates to IA-2, IA-2(1), IA-2(12), IA-5 IA-5(b), IA-5(c), IA-5(e), IA-5(g), IA-5(1), IA-5(11); CCI-000764, CCI-000765, CCI-001953, CCI-001954, CCI-001544, CCI-001989, CCI-000182, CCI-001610, CCI-000192, CCI-000193, CCI-000194, CCI-000205, CCI-001619, CCI-001611, CCI-001612, CCI-001613, CCI-001614, CCI-000195, CCI-001615, CCI-000196, CCI-000197, CCI-000199, CCI-000198, CCI-001616, CCI-001617, CCI-000200, CCI-001618, CCI-002041, CCI-002002, CCI-002003. }

This subpart indicates requirements for specific methods of identification and authentication for users and user accounts. Where these requirements conflict apply the following order of precedence: 1) If present, Device Specific Requirements take precedence over any other requirements; and then 2) multifactor authentication requirements take precedence over password requirements.

3.2.1 User Identification and Authentication for All System Types

Unless otherwise indicated, all user interfaces supporting accounts (either FULLY or MINIMALLY) must implement Identification and Authorization via passwords.

For LOW Impact Systems: User interfaces provided by computer operating systems must implement multifactor authentication via PIV.

3.2.2 User Identification and Authentication for Specific System Types

System specific requirements are in addition to and supersede those indicated for all system types. When no additional requirements are indicated for a specific system type the requirements for all systems still apply to that system type.

3.2.2.1 Lighting Control Systems Devices

No additional system specific requirements apply.

3.2.3 User Identification and Authentication for Specific Devices

3.2.4 Implementation of Identification and Authorization Requirements

Identification and Authorization must be met by one of the following methods:

- a. Direct implementation in the user interface.
- b. For user interfaces on a computer: inheriting the Identification and Authorization from the computer operating system, either by the operating system limiting access to specific applications by user, or by the application itself having permissions based on the user logged into the computer.
- c. For remote interfaces: an implementation shared between the remote user interface server and the remote user interface client. For example, a requirement for PIV authentication may be met on a remote user interface by a PIV reader on a web browser client which sends the authentication information via HTTPS to the remote server.

3.2.5 Password-Based Authentication Requirements

3.2.5.1 Passwords for Software and Applications Running on Computers

All software and applications running on computers supporting password-based authentication must enforce the following requirements:

- a. Minimum password length of 12 characters
- b. Password must contain at least one uppercase character.
- c. Password must contain at least one lowercase character.
- d. Password must contain at least one numeric character.
- e. Password must contain at least one special character. The list of supported special characters must include at least 4 separate characters.
- f. Password must have a minimum lifetime of 24 hours.
- g. Password must have a maximum lifetime of 60 days. When passwords expire, prompt users to change passwords. Do not lock accounts due to expired passwords.
- h. Password must differ from previous five passwords, where differ is defined as changing at least 50 percent of the characters (where location is significant, a character may be reused if it is in a different position).
- i. Passwords must be cryptographically protected during storage and transmission.

3.2.5.2 Passwords for Controllers FULLY Supporting Accounts

All controllers FULLY supporting accounts and supporting password-based authentication must enforce the following requirements:

- a. Minimum password length of twelve (12) characters
- b. Password must contain at least one uppercase character.
- c. Password must contain at least one lowercase character.
- d. Password must contain at least one numeric character.
- e. Password must contain at least one special character. The list of supported special characters must include at least 4 separate characters.
- f. Password must have a maximum lifetime of sixty (60) days. When passwords expire, prompt users to change passwords. Do not lock accounts due to expired passwords.
- g. Password must differ from previous five (5) passwords, where differ is defined as changing at least fifty percent of the characters.
- h. Passwords must be cryptographically protected during storage and transmission.

3.2.5.3 Passwords for Remote Interfaces

Passwords for connecting to a Remote User Interface supporting password-based authentication must enforce the following requirements:

- a. Minimum password length of twelve (12) characters
- b. Password must contain at least one uppercase character.
- c. Password must contain at least one lowercase character.
- d. Password must contain at least one numeric character.
- e. Password must contain at least one special character. The list of supported special characters must include at least 4 separate characters.
- f. Password must have a maximum lifetime of 60 days. When passwords expire, prompt users to change passwords. Do not lock accounts due to expired passwords.
- g. Password must differ from previous five passwords, where differ is defined as changing at least 50 percent of the characters (where location is significant, a character may be reused if it is in a different position).
- h. Passwords must be cryptographically protected during storage and transmission.

3.2.5.4 Passwords for Devices Minimally Supporting Accounts

Devices MINIMALLY supporting accounts must support passwords with a

minimum length of four characters.

3.2.5.5 Password Configuration and Reporting

For all devices with a password, coordinate the changing of passwords with the project site following testing of the system but prior to turnover to the Government. Coordinate with Password Point of Contact to determine appropriate project site personnel to complete password changes. Accompany identified personnel to each device with a password and instruct personnel on the process of changing password. Record the time, date and personnel present when each device's password is changed and submit a Password Change Summary Report documenting this information.

Provide the Password Summary Report electronically in both PDF and Microsoft Excel.

3.2.6 Authenticator Feedback

{For Government Reference Only: This subpart relates to IA-6; CCI-000206}

Devices must never show authentication information, including passwords, on a display. Devices that momentarily display a character as it is entered, and then obscure the character, are acceptable. For devices that have STIGs or SRGs related to obscuring of authenticator feedback (CCI-000206), comply with the requirements of those STIGS/SRGs.

3.3 CYBERSECURITY AUDITING

Where an auditing requirement exists for email notification, notify via email the application administrator and Information System Security Officer (ISSO) of the event. Coordinate with the Email Address Point of Contact for email addresses. If outgoing email is not available to the system, configure the system for these notifications for future support of outgoing email.

3.3.1 Audit Events, Content of Audit Records, and Audit Generation

{For Government Reference Only: This subpart (and its subparts) relates to AU-2(a), AU-2(c), AU-2(d), AU-3, AU-10, AU-12, AU-13(3), AU-14(b), AU-14(1), AU-14(2), AU-14(3), CM-5(1), SC-7 (9); CCI-000123, CCI-001571, CCI-000125, CCI-001485, CCI-000130, CCI-000131, CCI-000132, CCI-001230, CCI-000133, CCI-000134, CCI-001487, CCI-000166, CCI-001899, CCI-000169, CCI-001459, CCI-000171, CCI-000172, CCI-001910, CCI-001914, CCI-001919, CCI-001464, CCI-001462, CCI-001920, CCI-001814, CCI-002400. }

For devices that have STIG/SRGs related to audit events, content of audit records or audit generation, comply with the requirements of those STIG/SRGs.

If auditing requirements can be met using existing control system alarm or event capabilities, those existing capabilities may be used to meet these requirements.

3.3.1.1 Computers

For each computer, provide the capability to select audited events and the content of audit logs. Configure computers to audit the indicated events,

and to record the indicated information for each auditable event

3.3.1.1.1 Audited Events

Configure each computer to audit the following events:

- a. Successful and unsuccessful attempts to access, modify, or delete privileges, security objects, security levels, or categories of information (e.g. classification levels)
- b. Successful and unsuccessful logon attempts
- c. Successful logouts
- d. Privileged activities or other system level access
- e. Concurrent logons from different workstations
- f. Successful and unsuccessful accesses to objects
- g. All program initiations
- h. All direct access to the information system
- i. All account creations, modifications, disabling, and terminations.
- j. All kernel module load, unload, and restart

3.3.1.1.2 Audit Event Information To Record

Configure each computer to record, for each auditable event, the following information (where applicable to the event):

- a. What type of event occurred
- b. When the event occurred
- c. Where the event occurred
- d. The source of the event
- e. The outcome of the event
- f. The identity of any individuals or subjects associated with the event

3.3.1.2 For Lighting Control System Controller

3.3.1.2.1 Lighting Control System Controllers FULLY Supporting User Accounts

For each controller which FULLY supports accounts, provide the capability to select audited events and the content of audit logs. Configure controllers to audit the indicated events, and to record the indicated information for each auditable event.

3.3.1.2.1.1 Audited Events

Configure each controller to audit the following events:

- a. Successful and unsuccessful logon attempts to the controller
- b. Successful logouts
- c. All account creations, modifications, disabling, and terminations.
- d. All controller shutdown and startup

3.3.1.2.1.2 Audit Event Information To Record

Configure each controller to record, for each auditable event, the following information (where applicable to the event):

- a. what type of event occurred
- b. when the event occurred
- c. the identity of any individuals or subjects associated with the event

3.3.1.2.2 Other Lighting Control System Controllers

There are no requirements to perform auditing at Lighting field controllers that do not FULLY support accounts.

3.3.1.3 Default Requirements for Control System Controllers

For control system controllers where Audit Events, Content of Audit Records, and Audit Generation are not otherwise indicated in this Section:

3.3.1.3.1 Controllers Which FULLY Support Accounts

For each controller which FULLY supports accounts, provide the capability to select audited events and the content of audit logs. Configure controllers to audit the indicated events, and to record the indicated information for each auditable event.

3.3.1.3.1.1 Audited Events

Configure each controller to audit the following events:

- a. Successful and unsuccessful attempts to access, modify, or delete privileges, security objects, security levels, or categories of information (e.g. classification levels)
- b. Successful and unsuccessful logon attempts
- c. Successful logouts
- d. Concurrent logons from different workstations
- e. All account creations, modifications, disabling, and terminations.
- f. All kernel module load, unload, and restart

3.3.1.3.1.2 Audit Event Information To Record

Configure each controller to record, for each auditable event, the following information (where applicable to the event):

- a. what type of event occurred
- b. when the event occurred
- c. where the event occurred
- d. the source of the event
- e. the outcome of the event
- f. the identity of any individuals or subjects associated with the event

3.3.1.3.2 Controllers Which Do Not FULLY Support Accounts

For each controller which does not FULLY support accounts configure the controller to audit all controller shutdown and startup events and to record for each event the type of event and when the event occurred.

3.3.2 Audit Time Stamps

{For Government Reference Only: This subpart (and its subparts) relates to AU-8; CCI-000159, CCI-001889, CCI-001890.}

Any device (computer or controller) generating audit records must have an internal clock capable of providing time with a resolution of one second. Clocks must not drift more than 10 seconds per day. Configure the system so that each device (computer or controller) generating audit records maintains accurate time to within 1 second. Note that if the control system specifications include requirement for clocks, the most stringent requirement applies.

3.3.3 Auditing Front End Software

If there is no existing auditing front end software or the software is not compatible with the provided control systems, provide Auditing Front End Software with audit log import and upload, export, notification, and analysis functionality. The Auditing Front End Software may be provided as a component of the control system front end or as a separate software package, and a single package may serve multiple control systems provided under the same projects if they are sharing a cybersecurity authorization.

When the Auditing Front End Software is neither existing nor installed under the requirements of another Section, furnish the Auditing Front End Software media and license for subsequent Government installation. Submit copies of Auditing Front End Software if this function is not part of the software provided with the control system to meet requirements of other Sections.

3.3.3.1 Import and Upload Requirements

Auditing Front End Software must be capable of importing audit logs from the Device Audit Record Upload Software and of uploading audit logs over the network from all control system devices supporting network upload of audit logs.

3.3.3.2 Export Requirements

Auditing Front End Software must be capable of exporting to a file format supported by Microsoft Excel.

3.3.4 Audit Storage Capacity and Audit Upload

{For Government Reference Only: This subpart (and its subparts) relates to AU-4; CCI-001848, CCI-001849}

The creation of audit records must never interfere with normal device operation. Devices must cease collection of auditing information if required to maintain normal operation.

- a. For devices that have STIG/SRGs related to audit storage capacity (CCI-001848 or CCI-001849) comply with the requirements of those STIG/SRGs.
- b. For controllers capable of generating audit records, provide 60 days worth of secure local storage, assuming 10 auditable events per day.

3.3.4.1 Device Audit Record Upload Software

For each device (computer or controller) required to audit events and for which audit logs cannot be uploaded over the network by the Auditing Front End Software, provide and license to the Government software implementing a secure mechanism of uploading audit records from the device and exporting them to the Auditing Front End Software. Where different devices use different software, provide software of each type required to upload audit logs from all devices.

When Device Audit Record Upload Software is capable of uploading audit logs over the network, install Device Audit Record Upload Software on the same computer as the Auditing Front End Software. Submit copies of device audit record upload software if this function is not part of the software provided with the control system to meet requirements of other Sections. If there are no devices requiring this software, provide a document stating this in lieu of this submittal.

3.3.5 Response to Audit Processing Failures

{For Government Reference Only: This subpart (and its subparts) relates to AU-5; CCI-000139, CCI-000140, CCI-001490.}

In the case of a failure in the auditing system, computers associated with auditing must provide email notification. In case of an audit failure, if possible, continue to collect audit records by overwriting existing audit records.

3.4 REQUIREMENTS FOR LEAST FUNCTIONALITY

{For Government Reference Only: This subpart (and its subparts), along with the network communication report submittal specified elsewhere in this section, relates to CM-6(a), CM-6(c), CM-7, CM-7(1)(b), SC-41; CCI-000363, CCI-000364, CCI-000365, CCI-001588, CCI-001755, CCI-000381, CCI-000380, CCI-000382, CCI-001761, CCI-001762, CCI-002544, CCI-002545, CCI-002546. }

For devices that have a STIG or SRG related to Requirements for Least Functionality (such as configuration settings and port and device I/O access for least functionality), install and configure the device in accordance with that STIG or SRGs.

3.4.1 Device Capabilities

For Lighting Control Systems: Do not provide devices with remote user interfaces or with full user interfaces where one was not required.

For Other Control Systems: Do not provide devices with remote user interfaces or with full user interfaces where one was not required. Do not use a networked sensor or actuator where a non-networked sensor or actuator would suffice.

3.4.2 Software

For software that has a STIG or SRG related to Requirements for Least Functionality (such as configuration settings and port access for least functionality), install and configure the software in accordance with that STIG or SRG.

3.5 SYSTEM AND COMMUNICATION PROTECTION

3.5.1 Collaborative Computing

{For Government Reference Only: This subpart relates to SC-15(a), SC-15(b); CCI-001150, CCI-001152.}

Without explicit approval from the project site, control systems must not use collaborative computing technologies.

3.5.2 Denial of Service Protection

{For Government Reference Only: This subpart relates to SC-5, SC-39, SC-7(a); CCI-001093, CCI-002385, CCI-002386, CCI-002430, CCI-001097. }

To the greatest extent practical, implement control logic without reliance on the network. Except when required to meet the requirements of the control system Section (where the requirement can only be met using computer hardware), do not implement control logic in computers.

3.5.2.1 Default Requirements for MODERATE Impact Control Systems

Except for networked input and outputs on input-output buses specifically designed to provide high reliability or redundancy, sensors and actuators must not rely on the network to exchange data with the controller executing the sequence of operation which uses the sensor value or determines the actuator command.

Sensor values required by multiple devices may be shared over the network provided they are connected to a controller requiring the value for execution of the sequence and that controller shares the value on the

network.

3.6 SAFE MODE AND FAIL SAFE OPERATION

{For Government Reference Only: This subpart (and its subparts) relates to CP-12, SI-10(3), SI-17; CCI-002855, CCI-002856, CCI-002857, CCI-002754, CCI-002773, CCI-002774, CCI-002775}

For all control system components with an applicable STIG or SRG, configure the component in accordance with all applicable STIGs and SRGs.

3.7 SYSTEM MAINTENANCE TOOL SOFTWARE

{For Government Reference Only: This subpart (and its subparts) relates to MA-3; CCI-000865.}

Submit and license to the Government all software required to operate, maintain and modify the control system such the Government or their agents are able to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on the Contractor, Vendor or Manufacturer. Submit hard copies of user manuals for each software with the software submittal.

For software provided and licensed to the Government under the requirements of another Section, submit a statement indicating the Section and Submittal under which the software was provided. For software provided to meet the requirements of this Section and not provided and licensed under another Section, submit software and software user manuals on DVD or CD as a Technical Data Package and submit one hard copy of the software user manual for each piece of software.

3.8 DEVICE POWER

{For Government Reference Only: This subpart (and its subparts) relates to PE-11, PE-11(1); CCI-002955, CCI-000961. }

For LOW Impact Systems: Provide emergency power in accordance with the control system and equipment specification Sections.

3.9 VULNERABILITY SCANNING

{For Government Reference Only: This subpart (and its subparts) relates to RA-5 RA-5(a),RA-5(b),RA-5(c),RA-5(d); CCI-001054, CCI-001055, CCI-000156, CCI-001641, CCI-001643, CCI-001057, CCI-001058, CCI-001059. }

All IP devices must be scannable, such that the device can be scanned by industry standard IP network scanning utilities without harm to the device, application, or functionality.

3.9.1 Computers and Software Running on Computers

Computers and applications running on computers must meet relevant vulnerability scanning STIGs/SRGs and respond to approved DoD vulnerability scanning tools.

3.9.2 Controllers

Provide controllers that are scannable by standard control system discovery tools or control system browsers and return meaningful status information including the network inputs and outputs for the controller. This information must contain sufficient detail to detect vulnerabilities or exploits of the controller.

Provide all software needed to scan the control system as the Control System Scanning Tools submittal. If the software required to scan the system is already installed at the project site or is provided under a separate section instead provide a statement indicating this.

3.10 FIPS 201-2 REQUIREMENT

{For Government Reference Only: This subpart (and its subparts) relates to SA-4 (10); CCI-003116}

Devices in the following systems which implement PIV must be on the NIST FIPS 201-2 approved product list (<https://www.idmanagement.gov/approved-products-list/>): NONE.

3.11 SYSTEM AND INTEGRATION INTEGRITY

3.11.1 Malicious Code Protection

{For Government Reference Only: This subpart (and its subparts) relates to SI-3(c); CCI-001241, CCI-002623}

For all computers installed under this project, provide malware protection software media, provide licenses, and install and configure malware protection software as indicated. Coordinate with the Government Computer Access Point of Contact as required.

- a. Provide malware protection software licenses.
- b. Provide malware protection software media.
- c. Malware protection software will be Government installed.

3.12 CONTROL SYSTEM CYBERSECURITY TESTING

3.12.1 Control System Cybersecurity Testing Procedures

Prepare Control System Cybersecurity Testing Procedures explaining step-by-step, the actions and expected results that will demonstrate that the control system meets the requirements of this Section.

Submit 4 copies of the Control System Cybersecurity Testing Procedures. The Control System Cybersecurity Testing Procedures may be submitted as a Technical Data Package.

3.12.2 Control System Cybersecurity Testing Execution

Using the Control System Cybersecurity Testing Procedures verify that the control system meets the requirements of this Section. UNLESS GOVERNMENT

WITNESSING OF A TEST IS SPECIFICALLY WAIVED BY THE GOVERNMENT, PERFORM ALL TESTS WITH A GOVERNMENT WITNESS. If testing reveals deficiencies in the system, correct the deficiency and retest until successful.

3.12.3 Control System Cybersecurity Testing Report

Prepare and submit a Control System Cybersecurity Testing Report documenting all tests performed and their results. Include all tests in the Control System Cybersecurity Testing Procedures and any additional tests performed during testing. Document test failures and repairs conducted with the test results.

Submit four copies of the Control System Cybersecurity Testing Report. The Control System Cybersecurity Testing Report may be submitted as a Technical Data Package.

3.13 FIELD QUALITY CONTROL, CYBERSECURITY VALIDATION SUPPORT

In addition to testing and testing support required by other Sections, provide a minimum of 8 hours of technical support for cybersecurity testing of control systems to support the DoD Risk Management Framework process Cybersecurity assessment of the control system. This support is independent of (and in addition to) the Control System Cybersecurity Testing specified in this section.

3.14 CYBERSECURITY TRAINING

Provide eight hours of classroom and hands-on training for six Government personnel on the cybersecurity operation and maintenance of the control system provided. This training is in addition to and must be coordinated with control system training specified in other Sections.

The Government will provide the training location. Training must cover, at a minimum: (a) applying software and firmware updates, (b) user account creation, modification and deletion, (c) audit log upload procedures and (d) identification of privileged user interfaces and system impact of those interfaces. Training session must include a question and answer period during which government staff questions about cybersecurity aspects of the control system are answered.

-- End of Section --

SECTION 25 05 11.04

CYBERSECURITY FOR MODERATE IMPACT FIRE PROTECTION CONTROL SYSTEMS
05/21, CHG 1: 08/23

PART 1 GENERAL

Many subparts in this Section contain text in curly braces ("{" and "}") indicating which cybersecurity control and control correlation identifier (CCI) the requirements of the subpart relate to. The text inside these curly braces is for Government reference only and enables coordination of the requirements of this Section with the RMF process throughout the design and construction process. Text in curly braces are not contractor requirements.

This Section refers to Security Requirements Guide (SRGs) and Security Technical Implementation Guide (STIGs). STIGs and SRGs are available online at the Information Assurance Support Environment (IASE) website at <https://public.cyber.mil/stigs/downloads/> and an SRG/STIG Applicability Guide and Collection Tool is available at <https://public.cyber.mil/stigs/SCAP/>. Not all control system components have applicable STIGs or SRGs. The "Control Systems SRG" does not apply to work performed under this Section; all requirements within this section to apply applicable SRGs DO NOT include the "Control Systems SRG".

1.1 CONTROL SYSTEM APPLICABILITY

There are multiple versions of this Section associated with this project. Different versions have requirements applicable to different control systems. This specific Section applies only to the following control systems: MODERATE IMPACT FIRE PROTECTION CONTROL SYSTEM.

1.2 RELATED REQUIREMENTS

This section does not contain sufficient requirements to procure a control system and must be used in conjunction with other Sections which specify control systems. This Section adds cybersecurity requirements to the control systems specified in other Sections, and as these requirements are conditioned on the control system being provided, there may be requirements in this Section that will not apply to this project. All Sections containing facility-related control systems or control system components are related to the requirements of this Section. Review all specification sections to determine related requirements.

In cases where a requirement is specified in both this Section and in another Section, the more stringent requirement must be met. In cases where a requirement in this Section conflicts with the requirements of another Section such that both requirements cannot be met at the same time, request direction from the Contracting Officer Representative to determine which requirement applies to the project.

1.3 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 802.1x (2010) Local and Metropolitan Area
Networks - Port Based Network Access
Control

INTERNET ENGINEERING TASK FORCE (IETF)

IETF RFC 2819 (2000) Remote Network Monitoring (RMON)
Management Information Base (MIB)

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST FIPS 140-2 (2001) Security Requirements for
Cryptographic Modules

NIST FIPS 201-2 (2013) Personal Identity Verification
(PIV) of Federal Employees and Contractors

U.S. DEPARTMENT OF DEFENSE (DOD)

DODI 8551.01 (2014) Ports, Protocols, and Services
Management (PPSM)

DTM 08-060 (2008) Policy on Use of Department of
Defense (DoD) Information Systems -
Standard Consent Banner and User Agreement

1.4 DEFINITIONS

1.4.1 Administrator Account

An administrator account is an account with full permissions to a device, application, or operating system, including the ability to create and modify other user accounts.

Note that the operating system Administrator Account may be different than Administrator Accounts for applications hosted on that operating system. Also, most controllers will not have any support for accounts and will therefore not have an 'Administrator Account'.

1.4.2 Computer

A computer is one of the following:

- a. a device running a non-embedded desktop or server version of Microsoft Windows
- b. a device running a non-embedded version of MacOS
- c. a device running a non-embedded version of Linux

- d. a device running a version or derivative of the Android Operating System, where Android is considered separate from Linux
- e. a device running a version of Apple iOS

Unless otherwise indicated or clear from context use of the word "device" in this Section includes computers.

1.4.3 Controller

A device other than a computer or Ethernet switch. For Fire Protection systems this includes fire alarm control panels, remote operating consoles, and remote annunciators.

1.4.4 Mission Space

A device or media is in mission space if physical access to the device or media is controlled by the organization served by the device. For example, a VAV box controller in a suspended ceiling is in mission space if the VAV box serves that room; an electrical switchgear in an electrical room or an AHU in a mechanical room or on a rooftop may still be considered to be in mission space if the organization (mission) served by that switchgear or AHU controls access to the electrical room, mechanical room or rooftop.

1.4.5 Network

A network is a group of two or more devices that can communicate using a network protocol. Network protocols must provide a method for addressing devices on the network; a communication method that does not provide an addressing scheme is not a networked form of communication. Devices that communicate using a method of communication that does not support device addressing are not using a network.

1.4.6 Network Connected

A component is network connected (or "connected to a network") only when the device has a network transceiver which is directly connected to the network and implements the network protocol. A device lacking a network transceiver (and accompanying protocol implementation) can never be considered network connected. Note that (unlike many IT definitions of "Network Connected") a device connected to a non-IP network is still considered network connected (an IP connection or IP address is not required for a device to be network connected).

1.4.6.1 Wireless Network Connected

Any device that supports wireless network communication is network connected to a wireless network, regardless of whether the device is communicating using wireless. Unless physically disabled, devices with wireless transceivers support wireless, it is not sufficient to disable the wireless in software.

1.4.7 Network Media

The thing that provides the communication channel between the devices on

a network. Typically wire, but might include wireless, fiber optic, or even power line (some network protocols allow sending network signals over power wiring).

1.4.8 User Account Support Levels

The support for user accounts is categorized in this Section as one of three levels:

1.4.8.1 FULLY Supported

Device supports configurable individual accounts. Accounts can be created, deleted, modified, etc. Privileges can be assigned to accounts. These devices support user-based (as opposed to role-based) authentication.

1.4.8.2 MINIMALLY Supported

Device supports a small, fixed number of accounts (perhaps only one). Accounts cannot be modified. A device with only a "User" and an "Administrator" account would fit this category. Similarly, a device with two PINs for logon - one for restricted and one for unrestricted rights would fit here (in other words, the accounts do not have to be the traditional "username and password" structure). These devices typically only support role-based authentication.

Examples of devices which MINIMALLY support accounts are a) a variable frequency drive with a single account which requires a PIN for access to configuration; and b) a room lighting control touchpad interface that has a single account.

1.4.8.3 NOT Supported

Device does not support any Access Enforcement therefore the whole concept of "account" is meaningless.

1.4.9 Manual Local Input

Manual Local Inputs are system analog or binary inputs that are adjustable by a person but are, by intrinsic hardware design, very limited in potential capabilities. Manual Local Inputs do not have touch screens or full keyboards, but may have a few buttons or dials to allow input. Manual Local Inputs do not have full graphic screens or dot-matrix displays, but may have simple lights (LEDs) or 7-segment displays. Manual Local Inputs do not have any sort of menu structure, each button has a single well-defined function.

Examples of Manual Local Inputs are H-O-A switches, simple thermostats, and disconnect switches.

1.4.10 Card Reader

A card reader is an input/output device whose primary function is to assist in two-factor authentication. A card reader must have an interface to read data from a card and may be able to write data to a card. A card reader may have a means (such as buttons, keypad, touchscreen, etc.) for a user to input a PIN or password, as well as a limited display.

1.4.11 User Interface

A User Interface (UI) is something other than a Manual Local Input or Card Reader that allows a person to interact with the system or device. Note that while a Card Reader is not by itself a User Interface, a User Interface may contain a Card Reader in order for it to authenticate its user. Within control systems, there are a wide range of User Interfaces.

Two important distinctions are 1) whether the user interface is Local or Remote, and 2) the effective capabilities of the User Interface to alter data, which is the "privilege" of the user interface (where effective privilege available to a specific user at a specific user interface is the combination of the greatest privilege offered by the user interface and the specific account the user is logged into).

1.4.11.1 Local User Interface

A Local User Interface is a user interface where the physical hardware the user interacts with (keyboard, buttons, display, etc.) is physically part of the device being affected. All of the relevant characteristics of the user interface are embodied within a single device.

Note that a Local UI may be able to access data in a different device, Local versus Remote in this context refers to the user interface itself; the capability to access data in a different device is covered under "Full User Interface".

1.4.11.2 Remote User Interface

A Remote User Interface implements a Client/Server model where the physical hardware the user interacts with (Client) is physically distinct from the device being affected (Server). Most or all of the security and functionality characteristics of the user interface are defined by the Server, not the Client. The Client and Server communicate via a network connection. A common example of a remote user interface is a web-based interface where the browser (client) is generally on different hardware than the web server (server). A Remote UI remains a Remote UI even if the user happens to be at a Client on the same hardware as the Server. What is important is that a) the Client may be on different hardware than the Server and b) the majority of the security and functional characteristics of the interface are defined at the Server.

Note that this definition of "remote" is consistent with that generally used in the control industry but is not aligned with the NIST 800-53 definition of "Remote", which refers to "outside the system". The term "Remote" here better aligns with the NIST 800-53 definition of "Network" (remote from within the system) Access.

1.4.11.3 Types of User Interface (by capability)

User interfaces are also categorized by their capabilities as being Read Only, Limited, or Full.

1.4.11.3.1 Read-Only User Interface

A Read Only User Interface (also referred to as a View-Only User Interface) is a user interface that only allows for reading data, it does not allow (have the capability to) modify data. A Read Only User

Interface may be either Local or Remote. A User Interface that is configured to be Read Only (by some other means than the interface itself, such as using configuration software on a laptop) is a Read-Only Interface. Note a Read Only User Interface may have buttons (or touch screen, etc.) allowing the user to navigate through the presentation of data.

Examples of a Read Only User Interfaces are a) a publicly viewable "energy dashboard" showing weather data and energy usage within a building and b) digital wayfinding signage.

1.4.11.3.2 Limited User Interface

A Limited User Interface is a user interface that - by design - can only alter information local to the user interface. Note that the determination of "alter" includes only direct interactions, it explicitly excludes interactions that might occur as secondary effects. For example, an interface changing the flow setpoint in a pump controller is a direct interaction, the subsequent change in flow (as well as any subsequent downstream changes in valve position) are not direct interactions.

Two examples of LIMITED UIs are: a) a variable speed drive has a Limited Local User Interface which allows the user to change properties within the drive, but does not allow affecting things outside the drive; and b) a typical home WiFi Router has a Limited Remote User Interface which allows configuration of the Router, but does not allow direct interaction with other devices.

1.4.11.3.3 Full User Interface

A Full User Interface can alter information in devices outside the device with the user interface. For example, a typical Local Display Panel is a Full Local User Interface while a browser-based front end is a Full Remote User Interface.

1.4.11.3.4 View-Only User Interface

See Read-Only User Interface

1.4.11.4 Other User Interface Terminology

In addition to defining whether a user interface is a Hardware Limited, Read-Only, Limited or Full, and whether it is Local or Remote, user interfaces are classified by whether they are writable or privileged.

1.4.11.4.1 Writable User Interface

Any User Interface that is not Read-Only is Writable. (Limited User Interfaces and Full User Interfaces are both writable user interfaces (as they are capable of changing a value)).

1.4.11.4.2 Privileged User Interface

A Privileged UI is a UI that has sufficient capabilities or functionality that it requires specific cybersecurity measures to be put in place to limit its unauthorized use. Ultimately, whether a specific user interface is considered a Privileged User Interface must be determined by usage. Unless otherwise specified, user interfaces can be determined to be privileged or not using the following:

- a. Read-Only User Interfaces are not privileged user interfaces.
- b. User Interfaces that can inhibit or force the activation of a fire suppression system (e.g. such as for a pre-action or deluge system) are always privileged user interfaces. Other Full User interfaces for Fire Alarm Systems are privileged user interfaces as indicated and shown, or when another requirement of this Section establishes they are privileged. For all other systems, Full User Interfaces are privileged user interfaces.
- c. User interfaces that allow for configuration of auditing or allows for modification or deletion of audit logs are privileged user interface.
- d. User interfaces that allow for reprogramming a network connected device is a privileged user interface.
- e. Except as specified above, a Limited User Interface must be determined to be privileged or not based on the specific capabilities and use case of the user interface. In general however, user interfaces that do not offer significant capabilities above and beyond those available at that location via other means (e.g. such as a disconnect switch, breaker, or hand-off-auto switch, or physical attack) are not privileged.

1.4.12 Wireless Network

Any network that communicates without using wires or fiber optics as the communication media. Wireless networks include: WiFi, Bluetooth, ZigBee, cellular, satellite, 900 MHz radio, 2.4 GHz, free space optical, point-to-point laser, and IR.

1.4.13 Wired Broadcast Network

Wired Broadcast Networks are any network, such as powerline carrier networks and modem (wired telephony), that use wire-based technologies where there is not a clearly defined boundary for signal propagation.

1.5 ADMINISTRATIVE REQUIREMENTS

1.5.1 Points of Contact

Coordinate with the following Points of Contact as indicated in this Section and as required. Not all projects will require coordination with all Points of Contact. When coordination is required and no Point of Contact is indicated, coordinate with The Contracting Office Representative (COR).

- a. Government Computer Access Point of Contact: The Contracting Office Representative (COR)
- b. HTTPS Certificate Point of Contact: The Contracting Office Representative (COR)
- c. Email Address Point of Contact: The Contracting Office Representative (COR)
- d. Password Point of Contact: The Contracting Office Representative (COR)

- e. Mobile Code Point of Contact: The Contracting Office Representative (COR)
- f. PKI Infrastructure Point of Contact: The Contracting Office Representative (COR)

1.5.2 Coordination

Coordinate the execution of this Section with the execution of all other Sections related to control systems as indicated in the paragraph RELATED REQUIREMENTS. Items that must be considered when coordinating project efforts include but are not limited to:

- a. If requesting permission for wireless or wired broadcast communication, the Wireless and Wired Broadcast Communication Request submittal must be approved prior to control system device selection and installation.
- b. If requesting permission for alternate account lock permissions, the Device Account Lock Exception Request must be approved prior to control system device selection and installation.
- c. If requesting permission for the use of a device with multiple physical connections to IP networks, the Multiple IP Connection Device Request must be approved prior to control system device selection and installation.
- d. Wireless testing may be required as part of the control system testing. See requirements for the Wireless Communication Test Report submittal.
- e. If the Device Audit Record Upload Software is to be installed on a computer not being provided as part of the control system, coordination is required to identify the computer on which to install the software.
- f. The Cybersecurity Interconnection Schedule must be coordinated with other work that will be interconnected to, and interconnections must be approved by the Government before relying on them for system functionality.
- g. Cybersecurity testing support must be coordinated across control systems and with the Government cybersecurity testing schedule.
- h. Passwords must be coordinated with the indicated contact for the project site.
- i. If applicable, HTTPS web server certificates must be obtained from the indicated HTTPS Certificate Point of Contact.
- j. Contractor Computer Cybersecurity Compliance Statements must be provided for each contractor using contractor owned computers.

1.6 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for information only.

Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Device Account Lock Exception Request; G
Multiple Ethernet Connection Device Request; G
Contractor Computer Cybersecurity Compliance Statements; G
Contractor Temporary Network Cybersecurity Compliance Statements; G
Cybersecurity Interconnection Schedule; G
Protection of Information At Rest Proposal; G
Proposed STIG and SRG Applicability Report; G

SD-02 Shop Drawings

Network Communication Report; G
Cybersecurity Riser Diagram; G

SD-03 Product Data

Control System Cybersecurity Documentation; G

SD-06 Test Reports

Control System Cybersecurity Testing Procedures; G
Control System Cybersecurity Testing Report; G

SD-07 Certificates

Software Licenses; G

SD-11 Closeout Submittals

Password Change Summary Report; G
Enclosure Keys; G
Software and Configuration Backups; G
Auditing Front End Software; G
Device Audit Record Upload Software; G
System Maintenance Tool Software; G
Control System Scanning Tools; G
STIG, SRG and Vendor Guide Compliance Result Report; G
Control System Inventory Report; G

Integrity Verification Software; G

1.7 QUALITY CONTROL

1.7.1 Subject Matter Expert Qualifications

For the Moderate Impact Fire Protection control system:

For the position listed below resumes should be submitted to the Government within 14 days after notice to proceed. All certifications must be in effect prior to being hired.

These positions may serve across the contract and provide on-site support as required..

1.7.1.1 Cybersecurity Subject Matter Expert

The individual will over see all work within these specification. This position requires that the individual currently meets Information Assurance Management Level II Certification in accordance with DODD 8140 Cybersecurity Workforce Management and DODI 8570 Information Workforce Improvement Program.

Individuals for this position should have experience securing DoD Systems and with Risk Management Framework

1.8 CYBERSECURITY DOCUMENTATION

{For Government Reference Only: This subpart (and its subparts) relates to PL-7; CCI-003071}

1.8.1 Proposed STIG and SRG Applicability Report

For each model of network connected or network infrastructure device, use the DISA SRG/STIG Applicability Guide and Collection Tool (available at <https://public.cyber.mil/stigs/SCAP/> to identify applicable STIGs or SRGs and provide a report indicating applicable STIGs and SRGs for each model.

1.8.2 Cybersecurity Interconnection Schedule

{For Government Reference Only: This subpart relates to CA-3(b), PL-8, SC-7(9), SC-7(11); CCI-000258, CCI-003072, CCI-003073, CCI-003075, CCI-002398, CCI-002399, CCI-002401, CCI-002402, CCI-002403. For MODERATE Impact systems, this subpart also relates to SC-7; CCI-001126, CCI-001109}

Provide a completed Cybersecurity Interconnection Schedule documenting network connections between the installed system and other systems. Provide the following information for each device directly communicating between systems: Device Identifier, Device Description, Transport layer Protocol, Network Address, Port (if applicable), MAC (Layer 2) address (if applicable), Media, Application Protocol, Service (if applicable), Descriptive Purpose of communication. For communication with other authorized systems also provide the Foreign Destination and POC for Destination. For MODERATE Impact Systems: Also describe the impact of loss of the connection on the control system. If other control system

Sections used on this project include submittals documenting this information, provide copies of those submittals to meet this requirement.

In addition to the requirements of Section 01 33 00 SUBMITTAL PROCEDURES, provide the Cybersecurity Interconnection Schedule as an editable Microsoft Excel file (a template Cybersecurity Interconnection Schedule in Excel format is available at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1>)

1.8.3 Network Communication Report

{For Government Reference Only: This subpart (and its subparts) relates to CA-9, PL-8; CCI-002102, CCI-002103, CCI-002104, CCI-002105, CCI-003072, CCI-003073, CCI-003075 and also the submittal requirements associated with CM-6, CM-7, SC-8 and SC-41 including CM-7(3), CCI-000388.}

Provide a network communication report. For each networked device, document the communication characteristics of the device including communication protocols, services used, encryption employed, and a general description of what information is communicated over the network. For each device using IP, document all TCP and UDP ports used. For non-IP communications, document communication protocol and media used. If other control system Sections used on this project include submittals documenting this information, provide copies of those submittals to meet this requirement.

In addition to the requirements of Section 01 33 00 SUBMITTAL PROCEDURES, provide the Network Communication Report as an editable Microsoft Excel file.

1.8.4 Control System Inventory Report

{For Government Reference Only: This subpart (and its subparts) relates to CM-8(a), SI-17, IA-3; CCI-000389, CCI-000392, CCI-000398, CCI-002773, CCI-002774, CCI-002775, CCI-000777, CCI-000778, CCI-001958}

Provide a Control System Inventory report using the Inventory Spreadsheet listed under this Section at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1> documenting all networked devices, including network infrastructure devices. For each device provide all applicable information for which there is a field on the spreadsheet in accordance with the instructions on the spreadsheet.

In addition to the requirements of Section 01 33 00 SUBMITTAL PROCEDURES, provide the Control System Inventory Report as an editable Microsoft Excel file.

1.8.5 Software and Configuration Backups

{For Government Reference Only: This subpart (and its subparts) relates to CP-10; CCI-000550, CCI-000551, CCI-000552}

For each computer on which software is installed under this project, provide a recovery image of the final as-built computer. This image must allow for bare-metal restore such that restoration of the image is sufficient to restore system operation to the imaged state without the

need for re-installation of software. If additional user permissions are required to meet this requirement, coordinate the creation of the image with the identified Government Computer Access Point of Contact.

For all ethernet switches provide a backup of the switch configuration. For all controllers, provide a backup of the controller configuration and the source code for all loaded application programs (all software that is not common to every controller of the same manufacturer and model).

If any or all of these are provided under another Section, provide documentation indicating this and referencing those submittals.

1.8.6 Cybersecurity Riser Diagram

{For Government Reference Only: This subpart (and its subparts) relates to PL-2(a), PL-8; CCI-003051, CCI-003053, CCI-003072, CCI-003073, CCI-003075}

Provide a cybersecurity riser diagram of the complete control system including all network and device hardware. If the control system specifications require a riser diagram submittal, provide a copy of that submittal as the cybersecurity riser diagram. Otherwise, provide a riser diagram in one-line format.

1.8.7 STIG, SRG and Vendor Guide Compliance Result Report

For every component (device or software) with an applicable STIG or SRG in the Proposed STIG and SRG Applicability Report, provide a result report documenting compliance with the STIG or SRG requirements. For components which are scannable by the SCAP (security content automation protocol) tool (available online at <https://public.cyber.mil/stigs/scap>), provide the SCAP report and raw scan results.

For every component (device or software) with manufacturer provided cybersecurity documentation, procedure, or method for secure configuration or installation, provide a report documenting how the component was configured and any deviation from the manufacturer instructions.

1.8.8 Control System Cybersecurity Documentation

{For Government Reference Only: This subpart (and its subparts) relates to SA-5(a), SA-5(b), SA-5(c), SA-22(b); CCIs: CCI-003124, CCI-003125, CCI-003126, CCI-003127, CCI-003128, CCI-003129, CCI-003130, CCI-003131, CCI-003374}

Provide a Control System Cybersecurity Documentation submittal containing the indicated information for each device and software application.

1.8.8.1 Software Applications

For all software applications running on computers provide:

- a. administrator documentation that describes secure configuration of the software {For Government Reference Only: relates to CCI-003124}
- b. administrator documentation that describes secure installation of the software and software updates. {For Government Reference Only: relates to CCI-003125}

- c. administrator documentation that describes secure operation of the software {For Government Reference Only: relates to CCI-003124}
- d. administrator documentation that describes effective use and maintenance of security functions or mechanisms for the software {For Government Reference Only: relates to CCI-003127}
- e. administrator documentation that describes known vulnerabilities regarding configuration and use of administrative (i.e. privileged) functions for the software {For Government Reference Only: relates to CCI-003128}
- f. user documentation that describes user-accessible security functions or mechanisms in the software and how to effectively use those security functions or mechanisms {For Government Reference Only: relates to CCI-003129}
- g. user documentation that describes methods for user interaction which enables individuals to use the software in a more secure manner {For Government Reference Only: relates to CCI-003130}
- h. user documentation that describes user responsibilities in maintaining the security of the software {For Government Reference Only: relates to CCI-003131}

1.8.8.2 Default Requirements for Control System Devices

For control system devices where Control System Cybersecurity Documentation requirements are not otherwise indicated in this Section, provide:

- a. Documentation that describes secure configuration of the device {For Government Reference Only: relates to CCI-003124}
- b. Documentation that describes secure installation of the device {For Government Reference Only: relates to CCI-003125}
- c. Documentation that describes secure operation of the device {For Government Reference Only: relates to CCI-003124}
- d. Documentation that describes effective use and maintenance of security functions or mechanisms for the device {For Government Reference Only: relates to CCI-003127}
- e. Documentation that describes known vulnerabilities regarding configuration and use of administrative (i.e. privileged) functions for the device {For Government Reference Only: relates to CCI-003128}
- f. Documentation that describes user-accessible security functions or mechanisms in the device and how to effectively use those security functions or mechanisms {For Government Reference Only: relates to CCI-003129}
- g. Documentation that describes methods for user interaction which enables individuals to use the device in a more secure manner {For Government Reference Only: relates to CCI-003130}
- h. Documentation that describes user responsibilities in maintaining the

security of the device {For Government Reference Only: relates to CCI-003131}

- i. Documentation of the published last date of support by the manufacturer or indication that a published date is not available. {For Government Reference Only: relates to CCI-003374}

1.9 SOFTWARE LICENSING

{For Government Reference Only: This subpart (and its subparts) relates to SI-2(a), SI-2(c), SI-7(14); CCI-001227, CCI-002605, CCI-002737}

For all software provided that has not already been licensed to the government or project site, provide a license to the Government for a period of no less than 5 years, and the license must also include the following software updates:

- a. Security and bug-fix patches issued by the software manufacturer.
- b. Security patches to address any vulnerability identified in the National Vulnerability Database at <http://nvd.nist.gov> with a Common Vulnerability Scoring System (CVSS) severity rating of MEDIUM or higher.

Provide a single Software Licenses submittal with documentation of the software licenses for all software provided

1.10 CYBERSECURITY DURING CONSTRUCTION

{For Government Reference Only: This subpart (and its subparts) relates to AC-18, SA-3; CCI-000258}

In addition to the control system cybersecurity requirements indicated in this section, meet following requirement throughout the construction process.

1.10.1 Contractor Computer Equipment

Contractor owned computers may be used for construction. Contractor computers connected to the control system, control system network, or a control system component at any point during construction must meet the following requirements:

1.10.1.1 Operating System

The operating system must be an operating system currently supported by the manufacturer of the operating system. The operating system must be current on security patches and operating system manufacturer required updates.

1.10.1.2 Anti-Malware Software

The computer must run anti-malware software from a reputable software manufacturer. Anti-malware software must be a version currently supported by the software manufacturer, must be current on all patches and updates, and must use the latest definitions file. Computers used on this project

must be scanned using the installed software at least once per day.

1.10.1.3 Passwords and Passphrases

The passwords and passphrases for computers, applications, and web-based applications supporting passwords must be changed from their default values. Passwords must be a minimum of eight characters with a minimum of one uppercase letter, one lowercase letter, one number and one special character.

1.10.1.4 User-Based Authentication

Each user must have a unique account; sharing of a single account between multiple users is prohibited.

1.10.1.5 Demonstration of Compliance

The Government has the right to require demonstration of computer compliance with these requirements at any time during the project.

1.10.1.6 Contractor Computer Cybersecurity Compliance Statements

Provide a single submittal containing completed Contractor Computer Cybersecurity Compliance Statements for each company using contractor owned computers. Contractor Computer Cybersecurity Compliance Statements must use the template published at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1> Each Statement must be signed by a cybersecurity representative for the relevant company.

1.10.2 Temporary IP Networks

Temporary contractor-installed IP networks may be used during construction. When used, temporary contractor-installed IP networks connected to the control system, control system network, or a control system component at any point during construction must meet the following requirements:

1.10.2.1 Network Boundaries and Connections

The network must not extend outside the project site and must not connect to any IP network other than those specifically provided or furnished for this project. Any and all access to the network from outside the project site is prohibited.

1.10.3 Government Access to Network

Government personnel must be allowed to have complete and immediate access to the network at any time in order to verify compliance with this specification.

1.10.4 Temporary Wireless IP Networks

In addition to the other requirements on temporary IP networks, temporary wireless IP (WiFi) networks, when permitted, must not interfere with existing wireless networks, must use WPA2 security and must not broadcast the network name (SSID). Network names (SSID) for wireless networks must be changed from their default values.

1.10.5 Passwords and Passphrases

The passwords and passphrases for all network devices and network access must be changed from their default values. Passwords must be a minimum 8 characters with a minimum of one uppercase letter, one lowercase letter, one number and one special character.

1.10.6 Contractor Temporary Network Cybersecurity Compliance Statements

Provide a single submittal containing completed Contractor Temporary Network Cybersecurity Compliance Statements for each company implementing a temporary IP network. Contractor Temporary Network Cybersecurity Compliance Statements must use the template published at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1> Each Statement must be signed by a cybersecurity representative for the relevant company. If no temporary IP networks will be used, provide a single copy of the Statement indicating this.

1.11 CYBERSECURITY DURING WARRANTY PERIOD

All work performed on the control system after acceptance must be performed using Government Furnished Equipment or equipment specifically and individually approved by the Government.

PART 2 PRODUCTS

All products used on this project must meet the indicated requirements, but not all products specified here will be required by every project.

2.1 ETHERNET SWITCH

Provide Open Systems Interconnection (OSI) Layer 2 Ethernet switches with the following capabilities, and with an interface to support switch configuration for these capabilities:

2.1.1 Required Functionality

Switches must:

- a. Copper Ethernet ports must auto negotiate for 10, 100 and 1000 megabits-per-second links.
- b. Be capable of implementing port level access control by MAC address and limit the number of MAC addresses to one MAC address per port.
- c. For MODERATE Impact Systems, be capable of implementing per-port access control lists (ACLs) where the list can be filtered by source and destination IP addresses, and by source and destination UDP or TCP ports.
- d. Support Remote Network Monitoring (RMON) Port Analysis in accordance with IETF RFC 2819
- e. Configure target port and analysis port such that switch clones all target port traffic to analysis port.

2.1.2 Configuration Requirements

Switches must:

- a. Support configuration save and restore.
- b. Support both manual IP address assignment and acquisition of a dynamic IP address via Dynamic Host Configuration Protocol (DHCP).
- c. Be capable of limiting access for configuration to one or more of: a web interface using HTTPS, a command line interface using SSH, or an SNMP connection using SNMP version 3 or later.

2.2 DAISY CHAIN IP CONTROLLERS

Controllers used as Daisy Chain IP Controllers must be IP controllers with exactly two Ethernet network connections and basic built-in switch capabilities to allow implementation of an Ethernet network in a daisy chain architecture. Switches incorporated by Daisy Chain IP Controllers are not required to meet the requirements for Ethernet Switches as defined in this Section.

2.3 DATABASE AND WEB SERVER SOFTWARE FOR MODERATE IMPACT SYSTEMS

{For Government Reference Only: This subpart (and its subparts) relate to RA-5(1), RA-5(5); CCI-001062, CCI-001067, CCI-001645, CCI-002906}

All computer-based databases must use Microsoft SQL Server or Oracle or MySQL. All computer-based web interfaces must use Internet Information Services (IIS) or Apache as the web server.

PART 3 EXECUTION

3.1 CYBERSECURITY HARDENING AND CONFIGURATION GUIDES

Install, configure, and harden all hardware and software furnished on this project in accordance with manufacturer provided documentation, procedures, or methods for secure configuration or installation. Do not implement specific hardening actions if that action would conflict with required functionality or another requirement of this Section.

3.2 NETWORK REQUIREMENTS

3.2.1 Information Flow Enforcement In MODERATE Impact Systems

{For Government Reference Only: This subpart (and its subparts) relate to AC-4; CCI-001368, CCI-001414, CCI-001548, CCI-001549, CCI-001550, CCI-001551}

Install and configure Ethernet switches to block all traffic on all ports not required by the control protocol.

3.2.2 Wireless and Wired Broadcast Communication for Fire Protection Systems

The use of wireless and wired broadcast communication for fire protection systems within a facility is prohibited. Wireless communication may be used to provide communication from the fire protection system in a facility to the central monitoring station. Communication between the fire protection system and the central monitoring station must be via FIPS 140-2 certified devices.

3.2.3 Non-IP Control Networks

When control system specifications require particular communication protocols, use only those communication protocols and only as specified. Do not implement any other communication protocol.

When control system specifications do not indicate requirements for communication protocols, use only those protocols required for operation of the system as specified.

3.2.4 IP Control Networks

{For Government Reference Only: This subpart relates to CM-6(a), CM-7(a), CM-7(b), CM-7(1)(b), SC-41; CCI-001588, CCI-000381, CCI-000380, CCI-000381, CCI-000382, CCI-001761, CCI-001762, CCI-002544, CCI-002545, CCI-002546. For Moderate Impact Systems, this subpart (and its subparts) also relates to SC-5(1), SC-5(2); CCI-001094 CCI-001095}

IP Networks must be Ethernet networks and must use switches which are Ethernet Switches or Daisy Chain IP Controllers as defined in this Section. Do not use nonsecure functions, ports, protocols and services as defined in DODI 8551.01 unless those ports, protocols and services are specifically required by the control system specifications or otherwise specifically authorized by the Government. Do not use ports, protocols and services that are not specified in the control system specifications or required for operation of the control system.

For MODERATE Impact Systems, unless explicitly authorized, do not use IP networks if the same control functionality is available through the use of non-IP networks.

3.2.4.1 IP Network Routers

Do not install any device that performs IP routing.

3.2.4.2 IP Devices With Multiple Ethernet Connection

Except for Ethernet Switches and Daisy Chain IP Controllers, devices must not have more than one Ethernet connection to IP networks unless doing so is required by the project specifications and the specific application is approved. If a device with Multiple Ethernet Connections to IP networks is required, provide a Multiple Ethernet Connection Device Request using the Multiple Ethernet Connection Device Request Template at <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-05-1> to request approval for each device. If a device with Multiple Ethernet Connections to IP networks is not required, instead provide a document stating that no approval is being requested.

3.2.5 Cryptographic Protection

{For Government Reference Only: This subpart relates to IA-2(9), IA-3(1), SC-8, SC-13, SC-23(1), SC-23(3); CCI-001942, CCI-001959, CCI-001967, CCI-002418, CCI-002449, CCI-002450, CCI-001185, CCI-001188, CCI-001664.}

All remote user interfaces must use HTTPS for all traffic between the user interface client and user interface server.

For devices that have STIG/SRGs related to cryptographic protection (CCI-002450), comply with the requirements of those STIG/SRGs. Ensure that all network traffic is encrypted using NSA-approved cryptography; provision of digital signatures and hashing, and FIPS-validated cryptography.

3.2.6 Device Identification and Authentication

{For Government Reference Only: This subpart (and its subparts) relates to IA-3; CCI-000777, CCI-000778, CCI-001958. For MODERATE Impact systems, this subpart (and its subparts) also relates to SC-23, SC-23(5); CCI-001184, CCI-002470.}

All computers must support and implement IEEE 802.1x for device authentication to the network.

3.2.6.1 Default Requirements for Control System Devices

For control system devices where Device Identification and Authentication requirements are not otherwise indicated in this Section: Devices using Ethernet must support IEEE 802.1x. Devices using HTTP as a control protocol must use HTTPS instead.

3.2.7 Cryptographic Module Authentication

{For Government Reference Only: This subpart (and its subparts) relates to IA-7; CCI-000803}

For devices (including but not limited to NIST FIPS 140-2 compliant radios) that have STIG/SRGs related to cryptographic module authentication (CCI-000803), comply with the requirements of those STIG/SRGs.

3.3 ACCESS CONTROL REQUIREMENTS

3.3.1 User Accounts

{For Government Reference Only: This subpart (and its subparts) relate to AC-2(a), AC-3, AC-6(1), AC-6(10), AC-6(2), AC-6(9), CM-11(2), and IA-2; CCI-002110, CCI-000213, CCI-001558, CCI-002221, CCI-002222, CCI-002223, CCI-002235, CCI-000039, CCI-001419, CCI-002234, CCI-001812, and CCI-000764.

For MODERATE Impact systems, this subpart (and its subparts) also relate to AC-2 (2), AC-2(3), AC-2(4), AC-6(1), and CM-5(1); CCI-001361, CCI-000017, CCI-000217, CCI-000018, CCI-001403, CCI-001404, CCI-001405, CCI-002130, CCI-001683, CCI-001684, CCI-001685, CCI-001686, CCI-002132, CCI-001558, CCI-002221, CCI-002222, CCI-002223, CCI-001813.}

Any user interface supporting user accounts (either FULLY or MINIMALLY) must limit access according to specified limitations for each account. Install and configure any device having a STIG or SRG in accordance with

that STIG or SRG.

All user interfaces FULLY supporting accounts must implement user-based authentication where each account is uniquely assigned to a specific user. User interfaces FULLY supporting accounts must implement at least three (3) levels of user account privilege including: 1) an account with read-only permissions 2) an account with full permissions including account creation and modification and 3) an account with greater permissions than read-only but without account creation and modification.

3.3.1.1 Computers

All computer operating systems must FULLY support user accounts and implement accounts for access. Each control system software application not supporting accounts and running on a computer must be installed such that use of the software is restricted by the computer operating system to specific users.

Applications running on computers must not require the user be logged in to a computer operating system administrator account for normal operation. It is permissible to require the computer operating system administrator account for initial application installation and configuration.

3.3.1.2 Controllers

For user interfaces provided by controllers, provide access control in accordance with the User Interface Requirements table for the applicable control system and user interface type.

- a. For table entries of "NA": NA means Not Applicable, there are no interfaces in this category.
- b. For table entries of "None Required": The user interface is not required to support user accounts.
- c. For table entries of "MINIMALLY": The user interface must at least MINIMALLY support user accounts.
- d. For table entries of "FULLY": The user interface must at FULLY support user accounts.
- e. For table entries of "KEY": The user interface must have physical security in the form of either a key lock on the interface itself or be furnished inside a locked enclosure. Where this is required for a read only interface, this lock must prevent viewing of data on the interface; for other interfaces, this lock must prevent using the interface to alter data.
- f. For table entries of "Physical Security": For Local FULL interfaces, the interface must be located inside mission space. For Local Limited (not FULL) interfaces, the user interface must either a) be located within mission space or b) be protected by physical security at least as good as the control devices (and equipment controlled by the control devices) affected by the interface. For purposes of this requirement, 'affected' includes controllers with data that can be directly altered by the interface, as well as mechanical and/or electrical equipment directly controlled by those controllers, but

does not include other interactions.

- g. Entries of the form "X and Y" must meet both the requirement indicated for X and the requirement indicated for Y. For example, an entry of "MINIMALLY and Physical Security" indicates the user interface must both MINIMALLY support accounts and have physical security.
- h. Entries of the form "X or Y" must meet either the requirement indicated for X or the requirement indicated for Y.

3.3.1.2.1 Fire Protection Systems

User Interface Requirements for MODERATE Impact Fire Protection Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u> (See note 2)
Local Read Only	None Required
Local Limited, Non-privileged	None Required
Local Limited, Privileged	KEY and Physical Security
Local Full	KEY
Remote Read Only	None Required
Remote Limited, Non-Privileged	FULLY
Remote Limited, Privileged AND Remote Full	FULLY
Notes: 1)Local Read Only User Interfaces are always Non-Privileged 2)Devices outside mission space require physical security protections as indicated (in "PHYSICAL SECURITY IN MODERATE IMPACT SYSTEMS")	

3.3.1.3 Additional User Account Expiration Requirements In MODERATE Impact Systems:

In addition to other user account requirements, user account expiration and auditing must be configured as indicated.

3.3.1.3.1 For Control System Applications Running on Computers

If temporary accounts are supported, expire temporary accounts 72 hours after creation. Expire all other accounts after 35 days of inactivity.

3.3.1.3.2 For Other Control System Devices FULLY Supporting Accounts

If temporary accounts are supported, expire temporary accounts 72 hours after creation. Expire all other accounts after 365 days of inactivity.

3.3.2 Unsuccessful Logon Attempts

{For Government Reference Only: This subpart (and its subparts) relate to AC-7 (a), AC-7 (b); CCI-000043, CCI-000044, CCI-001423, CCI-002236, CCI-002237, CCI-002238}

Except for high availability user interfaces indicated as exempt, devices must meet the indicated requirements for handling unsuccessful logon attempts. If a device cannot meet these requirements, document device capabilities to protect from subsequent logon attempts and propose alternate protections in a Device Account Lock Exception Request submittal. Do not implement alternate protection measures in lieu of the indicated requirements without explicit permission from the Government. If no Device Account Lock Exceptions are requested, provide a document stating that no approval is being requested as the Device Account Lock Exception Request.

3.3.2.1 Devices MINIMALLY Supporting Accounts

For MODERATE Impact Systems: Devices which MINIMALLY (but not FULLY) support accounts must lock the user account accountafter five consecutive failed login attempts and must unlock the user account after 60 minutes have elapsed without an unsuccessful login attempt or by a successful login to a separate administrator account.

3.3.2.2 Devices FULLY Supporting Accounts

Devices which FULLY support accounts must meet the following requirements.

- a. It must lock the user account when three unsuccessful logon attempts occur within a 15 minute interval.
- b. Once an account is locked, the account must stay locked until unlocked by an administrator. If the account being locked is the sole administrator account on the device, the account must stay locked for 1 hour and then automatically unlock.
- c. Once the indicated number of unsuccessful logon attempts occurs, delay further logon prompts by 5 seconds.

3.3.2.3 High Availability Interfaces Exempt from Unsuccessful Logon Attempts Requirements

There are no high availability interfaces which are exempt from unsuccessful logon attempts requirements.

3.3.3 System Use Notification

{For Government Reference Only: This subpart (and its subparts) relates to AC-8; CCI-000048, CCI-002247, CCI-002243, CCI-002244, CCI-002245, CCI-002246, CCI-000050, CCI-002248}

3.3.3.1 System Use Notification for Remote User Interfaces

Remote user interfaces must display a warning banner meeting the requirements of DTM 08-060 on screen.

3.3.3.2 System Use Notification for Local User Interfaces

Devices which are connected to a network and have a local user interface must display a warning banner meeting the requirements of DTM 08-060 on the user interface screen if capable of doing so and must have a permanently affixed label with an approved banner from DTM 08-060 if unable to display the warning banner on the screen. Where it is impractical (perhaps due to device size) to affix the label to the device, affix the label to the device enclosure.

Labels must be machine printed or engraved, plastic or metal, designed for permanent installation, must use a font no smaller than 14 point, and must provide a high contrast between font and background colors.

3.3.4 Session Lock and Session Termination Requirements In MODERATE Impact Systems:

{For Government Reference Only: This subpart (and its subparts) relates to AC-11(a), AC-11(b), AC-11(1), AC-12, SC-10; AC-10; CCI-000058, CCI-000059, CCI-000056, CCI-000057, CCI-000060, CCI-002360, CCI-002361, CCI-001133, CCI-001134, CCI-000054, CCI-000055, CCI-002252}

3.3.4.1 Session Termination

When session termination is required for a User Interface, the User Interface must implement session termination a) based on manual initiation, or b) based on lack of activity, or c) based on either manual initiation or lack of activity, as indicated.

Session Termination must result in logging out the user. A logged out User Interface may only perform actions as indicated in the "Permitted Actions Without Identification or Authentication" subpart of this Section or display a publicly viewable image or blank screen. User Interfaces must remain logged out (session terminated) until a user enters correct authentication information, which must initiate a new session. All User Interfaces running on computers and all Remote User Interfaces must also terminate network connections as part of session termination.

3.3.4.2 Session Lock

When session lock is required for a User Interface, the User Interface must implement session lock a) based on manual initiation, or b) based on lack of activity, or c) based on either manual initiation or lack of activity, as indicated.

Session lock must result in the User Interface being suspended and the user interface must display a publicly viewable image or blank screen. No interaction with the user interface must be possible until either a) the same user enters valid authentication information, in which case that session must be continued, or b) until a different user enters valid authentication information at which point the first session must be terminated and a new session initiated for the new user.

3.3.5 Permitted Actions Without Identification or Authentication

{For Government Reference Only: This subpart (and its subparts) relates to AC-14; CCI-000061, CCI-000232}

The control system must require identification and authentication before allowing any actions except read-only actions by a user acting from a user interface which MINIMALLY or FULLY supports accounts.

3.3.6 Physical Security in MODERATE Impact Systems

{For Government Reference Only: This subpart relates to PE-3(1), PE-4, PE-5, SC-7(a), SC-7(c), SC-8, SC-8(1); CCI-000928, CCI-002926, CCI-000936, CCI-002930, CCI-002931, CCI-000937, CCI-001097, CCI-001109, CCI-002418, CCI-002419, CCI-002421.}

3.3.6.1 Physical Security for Media

3.3.6.1.1 Physical Security for Media Inside Mission Space

Install all non-IP network media located inside of the mission space in conduit. Install all IP network media located inside of the mission space in intermediate metallic conduit.

3.3.6.1.2 Physical Security for Media Outside Mission Space

Install all network media (both IP and non-IP) located outside of the mission space in rigid metallic conduit.

3.3.6.1.3 Physical Security for Non-Network Media in Fire Protection Systems

For Fire Suppression Systems which can be inhibited or forced to activate by manipulation of non-network wiring, install all non-network media outside of mission space, including analog and binary instrumentation wiring and power wiring, in rigid metallic conduit.

3.3.6.2 Physical Security for Devices

Install all devices (computers and controllers) which are located outside of mission space in lockable enclosures. (Recall that per definition of mission space, a room controlled by the mission is mission space regardless of whether it is contiguous with other mission space.)

Install all controllers connected to an IP network in lockable enclosures (both inside and outside of mission space).

3.3.6.2.1 Physical Security for Devices in Fire Protection Systems

For Fire Suppression systems with a release panel, install all components of the suppression system either inside mission space, or within locked enclosures. Components of these systems include: release panel, any relay or interface panels, analog and binary inputs or outputs, control valves, manual valves.

3.3.6.3 Physical Security for User Interfaces

Physical security requirements for User Interfaces are specified in the

preceding paragraphs of this Section.

3.3.7 Enclosures

Prior to final acceptance of the system, lock all lockable enclosures. Submit an Enclosure Keys submittal with all copies of keys for all enclosures and a key inventory list documenting all keys. Label each key with the matching enclosure identifier.

3.4 USER IDENTIFICATION AND AUTHENTICATION

{For Government Reference Only: This subpart (and its subparts) relates to IA-2, IA-2(1), IA-2(12), IA-5 IA-5(b), IA-5(c), IA-5(e), IA-5(g), IA-5(1), IA-5(11); CCI-000764, CCI-000765, CCI-001953, CCI-001954, CCI-001544, CCI-001989, CCI-000182, CCI-001610, CCI-000192, CCI-000193, CCI-000194, CCI-000205, CCI-001619, CCI-001611, CCI-001612, CCI-001613, CCI-001614, CCI-000195, CCI-001615, CCI-000196, CCI-000197, CCI-000199, CCI-000198, CCI-001616, CCI-001617, CCI-000200, CCI-001618, CCI-002041, CCI-002002, CCI-002003. For MODERATE Impact systems, this subpart also relates to AC-6 (1), AC-6(10), AC-6(2), AC-6(9)IA-2(4), IA-5(13); CCI-001558, CCI-002221, CCI-002222, CCI-002223, CCI-002235, CCI-000039, CCI-001419, CCI-002234, CCI-000768, CCI-002007.}

This subpart indicates requirements for specific methods of identification and authentication for users and user accounts. Where these requirements conflict apply the following order of precedence: 1) If present, Device Specific Requirements take precedence over any other requirements; and then 2) multifactor authentication requirements take precedence over password requirements.

3.4.1 User Identification and Authentication for All System Types

Unless otherwise indicated, all user interfaces supporting accounts (either FULLY or MINIMALLY) must implement Identification and Authorization via passwords.

For MODERATE Impact Systems: User interfaces provided by computer operating systems must implement multifactor authentication via PIV. User interfaces supporting accounts (FULLY or MINIMALLY) on computers must implement multifactor authentication via PIV. Devices with writable remote user interfaces must implement multifactor authentication via PIV. Devices with Privileged Remote User Interfaces must implement multifactor authentication via PIV. Software running on computers and computer operating systems must manage cached authenticators in accordance with the relevant STIGs. All other devices and software must not use cached authenticators.

3.4.2 User Identification and Authentication for Specific System Types

System specific requirements are in addition to and supersede those indicated for all system types. When no additional requirements are indicated for a specific system type the requirements for all systems still apply to that system type.

3.4.3 User Identification and Authentication for Specific Devices

There are no additional device specific user interface requirements

3.4.4 Implementation of Identification and Authorization Requirements

Identification and Authorization must be met by one of the following methods:

- a. Direct implementation in the user interface.
- b. For user interfaces on a computer: inheriting the Identification and Authorization from the computer operating system, either by the operating system limiting access to specific applications by user, or by the application itself having permissions based on the user logged into the computer.
- c. For remote interfaces: an implementation shared between the remote user interface server and the remote user interface client. For example, a requirement for PIV authentication may be met on a remote user interface by a PIV reader on a web browser client which sends the authentication information via HTTPS to the remote server.

3.4.5 Password-Based Authentication Requirements

3.4.5.1 Passwords for Software and Applications Running on Computers

All software and applications running on computers supporting password-based authentication must enforce the following requirements:

- a. Minimum password length of 12 characters
- b. Password must contain at least one uppercase character.
- c. Password must contain at least one lowercase character.
- d. Password must contain at least one numeric character.
- e. Password must contain at least one special character. The list of supported special characters must include at least 4 separate characters.
- f. Password must have a minimum lifetime of 24 hours.
- g. Password must have a maximum lifetime of 60 days. When passwords expire, prompt users to change passwords. Do not lock accounts due to expired passwords.
- h. Password must differ from previous five passwords, where differ is defined as changing at least 50 percent of the characters (where location is significant, a character may be reused if it is in a different position).
- i. Passwords must be cryptographically protected during storage and transmission.

3.4.5.2 Passwords for Controllers FULLY Supporting Accounts

All controllers FULLY supporting accounts and supporting password-based authentication must enforce the following requirements:

- a. Minimum password length of twelve (12) characters

- b. Password must contain at least one uppercase character.
- c. Password must contain at least one lowercase character.
- d. Password must contain at least one numeric character.
- e. Password must contain at least one special character. The list of supported special characters must include at least 4 separate characters.
- f. Password must have a maximum lifetime of sixty (60) days. When passwords expire, prompt users to change passwords. Do not lock accounts due to expired passwords.
- g. Password must differ from previous five (5) passwords, where differ is defined as changing at least fifty percent of the characters.
- h. Passwords must be cryptographically protected during storage and transmission.

3.4.5.3 Passwords for Remote Interfaces

Passwords for connecting to a Remote User Interface supporting password-based authentication must enforce the following requirements:

- a. Minimum password length of twelve (12) characters
- b. Password must contain at least one uppercase character.
- c. Password must contain at least one lowercase character.
- d. Password must contain at least one numeric character.
- e. Password must contain at least one special character. The list of supported special characters must include at least 4 separate characters.
- f. Password must have a maximum lifetime of 60 days. When passwords expire, prompt users to change passwords. Do not lock accounts due to expired passwords.
- g. Password must differ from previous five passwords, where differ is defined as changing at least 50 percent of the characters (where location is significant, a character may be reused if it is in a different position).
- h. Passwords must be cryptographically protected during storage and transmission.

3.4.5.4 Passwords for Devices Minimally Supporting Accounts

Devices MINIMALLY supporting accounts must support passwords with a minimum length of four characters.

3.4.5.5 Password Configuration and Reporting

For all devices with a password, coordinate the changing of passwords with the project site following testing of the system but prior to turnover to

the Government. Coordinate with Password Point of Contact to determine appropriate project site personnel to complete password changes. Accompany identified personnel to each device with a password and instruct personnel on the process of changing password. Record the time, date and personnel present when each device's password is changed and submit a Password Change Summary Report documenting this information.

Provide the Password Summary Report electronically in both PDF and Microsoft Excel.

3.4.6 Authenticator Feedback

{For Government Reference Only: This subpart relates to IA-6; CCI-000206}

Devices must never show authentication information, including passwords, on a display. Devices that momentarily display a character as it is entered, and then obscure the character, are acceptable. For devices that have STIGs or SRGs related to obscuring of authenticator feedback (CCI-000206), comply with the requirements of those STIGS/SRGs.

3.5 CYBERSECURITY AUDITING

Where an auditing requirement exists for email notification, notify via email the application administrator and Information System Security Officer (ISSO) of the event. Coordinate with the Email Address Point of Contact for email addresses. If outgoing email is not available to the system, configure the system for these notifications for future support of outgoing email.

3.5.1 Audit Events, Content of Audit Records, and Audit Generation

{For Government Reference Only: This subpart (and its subparts) relates to AU-2(a), AU-2(c), AU-2(d), AU-3, AU-10, AU-12, AU-13(3), AU-14(b), AU-14(1), AU-14(2), AU-14(3), CM-5(1), SC-7 (9); CCI-000123, CCI-001571, CCI-000125, CCI-001485, CCI-000130, CCI-000131, CCI-000132, CCI-001230, CCI-000133, CCI-000134, CCI-001487, CCI-000166, CCI-001899, CCI-000169, CCI-001459, CCI-000171, CCI-000172, CCI-001910, CCI-001914, CCI-001919, CCI-001464, CCI-001462, CCI-001920, CCI-001814, CCI-002400. For MODERATE Impact systems, this subpart (and its subparts) also relates to AU-3 (1); CCI-000135, CCI-001488}

For devices that have STIG/SRGs related to audit events, content of audit records or audit generation, comply with the requirements of those STIG/SRGs.

If auditing requirements can be met using existing control system alarm or event capabilities, those existing capabilities may be used to meet these requirements.

3.5.1.1 Computers

For each computer, provide the capability to select audited events and the content of audit logs. Configure computers to audit the indicated events, and to record the indicated information for each auditable event

3.5.1.1.1 Audited Events

Configure each computer to audit the following events:

- a. Successful and unsuccessful attempts to access, modify, or delete privileges, security objects, security levels, or categories of information (e.g. classification levels)
- b. Successful and unsuccessful logon attempts
- c. Successful logouts
- d. Privileged activities or other system level access
- e. Concurrent logons from different workstations
- f. Successful and unsuccessful accesses to objects
- g. All program initiations
- h. All direct access to the information system
- i. All account creations, modifications, disabling, and terminations. For MODERATE Impact Systems, also provide email notification when these audit events occur.
- j. All kernel module load, unload, and restart

3.5.1.1.2 Audit Event Information To Record

Configure each computer to record, for each auditable event, the following information (where applicable to the event):

- a. What type of event occurred
- b. When the event occurred
- c. Where the event occurred
- d. The source of the event
- e. The outcome of the event
- f. The identity of any individuals or subjects associated with the event
- h. For MODERATE Impact Systems: For all privileged commands, full-text recording of the executed command and the user executing the command

For MODERATE Impact Systems: Audit records must provide sufficient detail to reconstruct events to determine cause of compromise and magnitude of damage, malfunction, or security violation.

3.5.1.2 Default Requirements for Control System Controllers

For control system controllers where Audit Events, Content of Audit Records, and Audit Generation are not otherwise indicated in this Section:

3.5.1.2.1 Controllers Which FULLY Support Accounts

For each controller which FULLY supports accounts, provide the capability to select audited events and the content of audit logs. Configure controllers to audit the indicated events, and to record the indicated information for each auditable event.

3.5.1.2.1.1 Audited Events

Configure each controller to audit the following events:

- a. Successful and unsuccessful attempts to access, modify, or delete privileges, security objects, security levels, or categories of information (e.g. classification levels)
- b. Successful and unsuccessful logon attempts
- c. Successful logouts
- d. Concurrent logons from different workstations
- e. All account creations, modifications, disabling, and terminations. For MODERATE Impact Systems, also provide email notification when these audit events occur.
- f. All kernel module load, unload, and restart
- g. For privileged user interfaces in MODERATE Impact Systems: All user commands.

3.5.1.2.1.2 Audit Event Information To Record

Configure each controller to record, for each auditable event, the following information (where applicable to the event):

- a. what type of event occurred
- b. when the event occurred
- c. where the event occurred
- d. the source of the event
- e. the outcome of the event
- f. the identity of any individuals or subjects associated with the event
- g. For privileged user interfaces in MODERATE Impact Systems: Full text recording of the executed command and the user executing the command.

For MODERATE Impact Systems: Audit records must provide sufficient detail to reconstruct events to determine cause of compromise and magnitude of damage, malfunction, or security violation

3.5.1.2.2 Controllers Which Do Not FULLY Support Accounts

For each controller which does not FULLY support accounts configure the controller to audit all controller shutdown and startup events and to record for each event the type of event and when the event occurred.

3.5.2 Audit Time Stamps

{For Government Reference Only: This subpart (and its subparts) relates to AU-8; CCI-000159, CCI-001889, CCI-001890. For MODERATE Impact systems, this subpart (and its subparts) also relates to AU-8 (1); CCI-001891, CCI-001892, CCI-002046.}

Any device (computer or controller) generating audit records must have an internal clock capable of providing time with a resolution of one second. Clocks must not drift more than 10 seconds per day. Configure the system so that each device (computer or controller) generating audit records maintains accurate time to within 1 second. Note that if the control system specifications include requirement for clocks, the most stringent requirement applies.

3.5.3 Auditing Front End Software

If there is no existing auditing front end software or the software is not compatible with the provided control systems, provide Auditing Front End Software with audit log import and upload, export, notification, and analysis functionality. The Auditing Front End Software may be provided as a component of the control system front end or as a separate software package, and a single package may serve multiple control systems provided under the same projects if they are sharing a cybersecurity authorization.

When the Auditing Front End Software is neither existing nor installed under the requirements of another Section, furnish the Auditing Front End Software media and license for subsequent Government installation. Submit copies of Auditing Front End Software if this function is not part of the software provided with the control system to meet requirements of other Sections.

3.5.3.1 Import and Upload Requirements

Auditing Front End Software must be capable of importing audit logs from the Device Audit Record Upload Software and of uploading audit logs over the network from all control system devices supporting network upload of audit logs.

3.5.3.2 Export Requirements

Auditing Front End Software must be capable of exporting to a file format supported by Microsoft Excel.

3.5.3.3 Notification Of Audit Failure in Devices in MODERATE Impact Systems

The auditing front end software must be capable of receiving notifications of audit failure from control system devices and computers and be able to provide email notification based on receipt of the notification.

3.5.3.4 Audit Reduction and Report Generation In MODERATE Impact Systems

{For Government Reference Only: This subpart (and its subparts) relates to AU-6(4), AU-7(a), AU-7(b), AU-7(1), AU-12(1); CCI-000154, CCI-001875, CCI-001876, CCI-001877, CCI-001878, CCI-001879, CCI-001880, CCI-001881, CCI-001882, CCI-000158, CCI-000173, CCI-000174, CCI-001577.}

Auditing Front End Software must provide audit reduction and reporting

capabilities that supports on-demand review and analysis, on demand reporting, and after the fact investigations of security incidents. The software must be able to combine audit records from all components within the system and analyze them as a single audit record. The software must correct for discrepancies in timestamps of audit logs from different sources and be able to account for discrepancies up to 2 seconds between sources. The software must not alter original audit record content or time ordering of audit records. The software must have the capability to filter audit records using user-defined fields within the audit records.

The audit reduction and reporting capabilities may incorporate third party application, such as Excel or Access.

3.5.4 Audit Storage Capacity and Audit Upload

{For Government Reference Only: This subpart (and its subparts) relates to AU-4; CCI-001848, CCI-001849}

The creation of audit records must never interfere with normal device operation. Devices must cease collection of auditing information if required to maintain normal operation.

- a. For devices that have STIG/SRGs related to audit storage capacity (CCI-001848 or CCI-001849) comply with the requirements of those STIG/SRGs.
- b. For controllers capable of generating audit records, provide 60 days worth of secure local storage, assuming 10 auditable events per day.

3.5.4.1 Audit Log Storage Notification In MODERATE Impact Systems

{For Government Reference Only: This subpart (and its subparts) relates to AU-5(1); CCI-001855.}

Controllers storing audit logs must provide notification when audit logs reach 75 percent of capacity either directly through email or indirectly by sending a notification to a computer, and the computer sending an email. Computers storing audit logs must provide notification when audit logs reach 75 percent of capacity directly through email.

3.5.4.2 Device Audit Record Upload Software

For each device (computer or controller) required to audit events and for which audit logs cannot be uploaded over the network by the Auditing Front End Software, provide and license to the Government software implementing a secure mechanism of uploading audit records from the device and exporting them to the Auditing Front End Software. Where different devices use different software, provide software of each type required to upload audit logs from all devices.

When Device Audit Record Upload Software is capable of uploading audit logs over the network, install Device Audit Record Upload Software on the same computer as the Auditing Front End Software. Submit copies of device audit record upload software if this function is not part of the software provided with the control system to meet requirements of other Sections.

If there are no devices requiring this software, provide a document stating this in lieu of this submittal.

3.5.5 Response to Audit Processing Failures

{For Government Reference Only: This subpart (and its subparts) relates to AU-5; CCI-000139, CCI-000140, CCI-001490.}

In the case of a failure in the auditing system, computers associated with auditing must provide email notification. For MODERATE Impact systems, the computer must also notify the associated auditing front end software. In case of an audit failure, if possible, continue to collect audit records by overwriting existing audit records.

For MODERATE Impact Systems: In the case of an audit failure at a controller performing auditing, the device must notify the associated auditing front end software of the audit failure if able, and must continue to collect audit records by overwriting existing audit records if able. The auditing front end software must provide notification as indicated, treating the notification of failure from the device as a failure in the auditing system.

3.6 REQUIREMENTS FOR LEAST FUNCTIONALITY

{For Government Reference Only: This subpart (and its subparts), along with the network communication report submittal specified elsewhere in this section, relates to CM-6(a), CM-6(c), CM-7, CM-7(1)(b), SC-41; CCI-000363, CCI-000364, CCI-000365, CCI-001588, CCI-001755, CCI-000381, CCI-000380, CCI-000382, CCI-001761, CCI-001762, CCI-002544, CCI-002545, CCI-002546. For MODERATE Impact systems, this subpart (and its subparts) also relates to CM-7(2), CM-7(5)(a), CM-7(5)(b); CCI-000381, CCI-000380, CCI-000382, CCI-001761, CCI-001762}

For devices that have a STIG or SRG related to Requirements for Least Functionality (such as configuration settings and port and device I/O access for least functionality), install and configure the device in accordance with that STIG or SRGs.

3.6.1 Device Capabilities

Do not provide devices with remote user interfaces or full user interfaces where one was not required. Do not use a networked sensor or actuator where a non-networked sensor or actuator would suffice.

Unless specifically required by the government, do not provide a capability to update device firmware over the network.

3.6.2 Software

For software that has a STIG or SRG related to Requirements for Least Functionality (such as configuration settings and port access for least functionality), install and configure the software in accordance with that STIG or SRG.

For MODERATE Impact Systems: Do not provide (install) software that is not specifically required to meet a contract requirement. Do not implement functionality within software that is not specifically required to meet contract requirements.

3.7 SYSTEM AND COMMUNICATION PROTECTION

3.7.1 Collaborative Computing

{For Government Reference Only: This subpart relates to SC-15(a), SC-15(b); CCI-001150, CCI-001152.}

Without explicit approval from the project site, control systems must not use collaborative computing technologies.

3.7.2 Denial of Service Protection and Application Partitioning In MODERATE Impact Systems:

{For Government Reference Only: This subpart relates to SC-5, SC-39, SC-7(a); CCI-001093, CCI-002385, CCI-002386, CCI-002430, CCI-001097. For MODERATE Impact systems, this subpart also relates to SC-2; CCI-001082.}

To the greatest extent practical, implement control logic without reliance on the network. Except when required to meet the requirements of the control system Section (where the requirement can only be met using computer hardware), do not implement control logic in computers. For MODERATE Impact systems, do not implement control logic in a device providing (i.e. acting as a server for) a Full Remote User Interface.

3.7.2.1 Default Requirements for MODERATE Impact Control Systems

Except for networked input and outputs on input-output buses specifically designed to provide high reliability or redundancy, sensors and actuators must not rely on the network to exchange data with the controller executing the sequence of operation which uses the sensor value or determines the actuator command.

Sensor values required by multiple devices may be shared over the network provided they are connected to a controller requiring the value for execution of the sequence and that controller shares the value on the network.

3.7.3 Mobile Code In MODERATE Impact Systems:

{For Government Reference Only: This subpart relates to SC-18(a), SC-18(b), SC-18(c), SC-18(1), SC-18(3), SC-18(4); CCI-001160, CCI-001161, CCI-001162, CCI-001163, CCI-001164, CCI-001165, CCI-001166, CCI-001662, CCI-002457, CCI-002458, CCI-001169, CCI-001695, CCI-001170, CCI-002469}

Devices with STIGs/SRGs related to Mobile Code and to Security Control SC-18 must be installed in accordance with the relevant STIGs/SRGs. All remote user interfaces must meet the requirements of the "Web Browsers and Application SRG".

Mobile code may only be downloaded from a specifically authorized mobile code repository. Coordinate with the Mobile Code Point of Contact for the location of a repository.

3.7.4 Protection of Information at Rest In MODERATE Impact Systems:

{For Government Reference Only: This subpart relates to SC-28, SC-28(1); CCI-001199, CCI-002472, CCI-002475, CCI-002476}

Computers must protect information at rest in accordance with applicable STIGs.

Any control system device storing personally identifiable information (PII), controlled unclassified information (CUI), or classified information must be protected by an Information At Rest encryption solution or by a physical security solution. Provide a Protection of Information At Rest Proposal indicating each device storing PII, CUI, or classified information and the encryption or physical security solution proposed for that device for government approval. If no devices stores PII, CUI, or classified information, provide a document stating this as the Protection of Information At Rest Proposal submittal. Do proceed with device selection and installation until the Protection of Information At Rest Proposal is approved. Once approved, implement approved Information At Rest protections.

3.7.5 Process Isolation and Boundary Protection in Moderate Impact Fire Protection Systems

{For Government Reference Only: This subpart relates to SC-7(a), SC-7(c), SC-7(4)(a), SC-7(4)(c), SC-7(5), SC-7(7), SC-7(9)(a), SC-7(11), SC-7(13), SC-7(13), SC-7(18); CCI-001097, CCI-001098, CCI-001102, CCI-002396, CCI-001109, CCI-002397, CCI-002398, CCI-002399, CCI-002403, CCI-001120, CCI-001119, CCI-001126}

3.7.5.1 Radio Interfaces for Fire Protection Systems

When radios interfacing a local fire protection system to a supervisory system are not NIST FIPS 140-2 validated, use a relay panel interface between the local fire protection system and the radio. Install and configure the relay panel to prohibit initiating any action within the local fire protection system other than causing the system to play a pre-recorded message or causing the system to play a live audio message. Install relays using the normally open contact such that they pass a signal when they close, and so that a relay that loses power or has a failed coil does not pass a signal

3.7.5.2 Fire Suppression System Network Isolation

For fire suppression systems including a release panel, any network used in these systems must be dedicated to these systems and must be isolated from any other network, including other components of the Fire Alarm and Fire Suppression systems. Use only dry contacts and relays to transfer signals from these systems to any other systems. Install relays using the normally open contact such that they pass a signal when they close, and so that a relay that loses power or has a failed coil does not pass a signal

3.8 SAFE MODE AND FAIL SAFE OPERATION

{For Government Reference Only: This subpart (and its subparts) relates to CP-12, SI-10(3), SI-17; CCI-002855, CCI-002856, CCI-002857, CCI-002754,

CCI-002773, CCI-002774, CCI-002775}

For all control system components with an applicable STIG or SRG, configure the component in accordance with all applicable STIGs and SRGs.

3.9 SYSTEM MAINTENANCE TOOL SOFTWARE

{For Government Reference Only: This subpart (and its subparts) relates to MA-3; CCI-000865.}

Submit and license to the Government all software required to operate, maintain and modify the control system such the Government or their agents are able to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on the Contractor, Vendor or Manufacturer. Submit hard copies of user manuals for each software with the software submittal.

For software provided and licensed to the Government under the requirements of another Section, submit a statement indicating the Section and Submittal under which the software was provided. For software provided to meet the requirements of this Section and not provided and licensed under another Section, submit software and software user manuals on DVD or CD as a Technical Data Package and submit one hard copyhard copies of the software user manual for each piece of software.

3.10 DEVICE POWER

{For Government Reference Only: This subpart (and its subparts) relates to PE-11, PE-11(1); CCI-002955, CCI-000961. For MODERATE Impact systems, this subpart (and its subparts) also relates to PE-9, PE-9(1); CCI-000952, CCI-002953, CCI-002954.}

For MODERATE Impact Systems: Provide control system with power supply meeting or exceeding the reliability of the controlled equipment. Powering control system devices using the same power source as the equipment controlled by the device is a permissible method of meeting this requirement. Without explicit approval from the government, do not install local uninterruptible power supplies (UPSs) as a source of device power.

3.10.1 Device Behavior on Loss of Power In MODERATE Impact Systems:

Application programs and configuration settings must be stored in devices in manner such that a loss of power does not result in a loss of the application program or configuration settings: Loss of power must never result in the loss of application programs, regardless of the length of time power is lost; and loss of power for less than 2,500 hours must not result in the loss of configured settings.

In the event of a loss of power, when power is restored, controllers and computers executing control logic (and the underlying equipment) must recover and resume their normal sequences of operation. Note that the sequence of operation may require specific actions (e.g. startup sequences) upon recovery from loss of power.

3.11 VULNERABILITY SCANNING

{For Government Reference Only: This subpart (and its subparts) relates to RA-5 RA-5(a),RA-5(b),RA-5(c),RA-5(d); CCI-001054, CCI-001055, CCI-000156, CCI-001641, CCI-001643, CCI-001057, CCI-001058, CCI-001059. For MODERATE Impact systems, this subpart (and its subparts) also relates to RA-5(1), RA-5(5); CCI-001062, CCI-001067, CCI-001645, CCI-002906.}

All IP devices must be scannable, such that the device can be scanned by industry standard IP network scanning utilities without harm to the device, application, or functionality.

3.11.1 Computers and Software Running on Computers

Computers and applications running on computers must meet relevant vulnerability scanning STIGs/SRGs and respond to approved DoD vulnerability scanning tools.

3.11.2 Controllers

Provide controllers that are scannable by standard control system discovery tools or control system browsers and return meaningful status information including the network inputs and outputs for the controller. This information must contain sufficient detail to detect vulnerabilities or exploits of the controller.

Provide all software needed to scan the control system as the Control System Scanning Tools submittal. If the software required to scan the system is already installed at the project site or is provided under a separate section instead provide a statement indicating this.

3.12 FIPS 201-2 REQUIREMENT

{For Government Reference Only: This subpart (and its subparts) relates to SA-4 (10); CCI-003116}

Devices in the following systems which implement PIV must be on the NIST FIPS 201-2 approved product list (<https://www.idmanagement.gov/approved-products-list/>): NONE.

3.13 SYSTEM AND INTEGRATION INTEGRITY

3.13.1 Malicious Code Protection

{For Government Reference Only: This subpart (and its subparts) relates to SI-3(c); CCI-001241, CCI-002623}

For all computers installed under this project, provide malware protection software media, provide licenses, and install and configure malware protection software as indicated. Coordinate with the Government Computer Access Point of Contact as required.

- a. Provide malware protection software licenses.
- b. Provide malware protection software media.
- c. Install and configure malware protection software in accordance with the relevant STIGs.

3.13.2 Software, Firmware, and Information Integrity In MODERATE Impact Systems:

{For Government Reference Only: This subpart relates to CM-5(3);
CCI-001749, CCI-002704, CCI-002726}

If there exists Integrity Verification Software that can check boot process, software, firmware, or information in the control system and verify its integrity, provide it. If no such software exists provide a statement to this affect in lieu of the software.

The system prevents the installation of software and firmware without verification of the digital signature using an approved certificate.

3.14 CONTROL SYSTEM CYBERSECURITY TESTING

{For Government Reference Only: For MODERATE Impact systems, this subpart (and its subparts) relates to SA-11(a), SA-11(b), SA-11(c), SA-11(d), SA-11(e); CCI-003171, CCI-003172, CCI-003173, CCI-003174, CCI-003175, CCI-003176, CCI-003177, CCI-003178.}

3.14.1 Control System Cybersecurity Testing Procedures

Prepare Control System Cybersecurity Testing Procedures explaining step-by-step, the actions and expected results that will demonstrate that the control system meets the requirements of this Section.

Submit 4 copies of the Control System Cybersecurity Testing Procedures. The Control System Cybersecurity Testing Procedures may be submitted as a Technical Data Package.

3.14.2 Control System Cybersecurity Testing Execution

Using the Control System Cybersecurity Testing Procedures verify that the control system meets the requirements of this Section. UNLESS GOVERNMENT WITNESSING OF A TEST IS SPECIFICALLY WAIVED BY THE GOVERNMENT, PERFORM ALL TESTS WITH A GOVERNMENT WITNESS. If testing reveals deficiencies in the system, correct the deficiency and retest until successful.

3.14.3 Control System Cybersecurity Testing Report

Prepare and submit a Control System Cybersecurity Testing Report documenting all tests performed and their results. Include all tests in the Control System Cybersecurity Testing Procedures and any additional tests performed during testing. Document test failures and repairs conducted with the test results.

Submit four copies of the Control System Cybersecurity Testing Report. The Control System Cybersecurity Testing Report may be submitted as a Technical Data Package.

3.15 FIELD QUALITY CONTROL, CYBERSECURITY VALIDATION SUPPORT

In addition to testing and testing support required by other Sections, provide a minimum of 16 hours of technical support for cybersecurity

testing of control systems to support the DoD Risk Management Framework process Cybersecurity assessment of the control system. This support is independent of (and in addition to) the Control System Cybersecurity Testing specified in this section.

3.16 CYBERSECURITY TRAINING

Provide eight hours of classroom and hands-on training for six Government personnel on the cybersecurity operation and maintenance of the control system provided. This training is in addition to and must be coordinated with control system training specified in other Sections.

The Government will provide the training location. Training must cover, at a minimum: (a) applying software and firmware updates, (b) user account creation, modification and deletion, (c) audit log upload procedures and (d) identification of privileged user interfaces and system impact of those interfaces. Training session must include a question and answer period during which government staff questions about cybersecurity aspects of the control system are answered.

-- End of Section --

SECTION 25 08 10

UTILITY MONITORING AND CONTROL SYSTEM TESTING
05/21

PART 1 GENERAL

1.1 DEFINITIONS

In addition to the definitions provided in this Section, 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and 25 10 10 UTILITY MONITORING AND CONTROL (UMCS) FRONT END AND INTEGRATION contain definitions related to this Section.

1.1.1 Algorithm

A set of well-defined rules or procedures for solving a problem or providing an output from a specific set of inputs.

1.1.2 Analog

A signal that can take on continuous (as opposed to discrete) values. Sensors (e.g. temperature, pressure, flow) typically provide analog signals as outputs to represent the measured variable. Within the UMCS, analog signals are generally represented by either 0-10 volt or a 4-20 milliamp signal.

1.1.3 Binary

A two-state system where an "ON" condition is represented by a high signal level and an "OFF" condition is represented by a low signal level.

1.1.4 Change-Of-Value (COV)

A type of data transmission over the network where the point value is transmitted over the network only when its value changes. COV is an efficient use of network bandwidth.

1.1.5 Control Wiring

This includes conduit, wire, and wiring devices to install complete HVAC control systems, including motor control circuits, interlocks, sensors, PE and EP switches, and like devices. This also includes all wiring from node to node, and nodes to all sensors and points defined in the I/O summary shown on drawings or specified herein, and required to execute the sequence of operation. Does not include line voltage power wiring.

1.1.6 Demand

The maximum rate of use of electrical energy averaged over a specific interval of time, usually expressed in kW.

1.1.7 Graphical User Interface (GUI)

Human-machine interfacing allows the operator to manage, command, monitor, and program the system.

1.1.8 Integration

Establishing communication between two or more systems to create a single system.

1.1.9 Protocol

In control systems, "protocol" is generally shorthand for "communication protocol"; a defined method by which digital information is exchanged electronically. Often more than one protocol is used in a BAS, for example, a typical BACnet system will use at a minimum (in addition to BACnet/IP and BACnet MS/TP) IP, UDP, ARP, Ethernet, and RS-485 protocols (and this does not include any protocols used internally in the front end or for communication with front end client workstations).

1.2 ADMINISTRATIVE REQUIREMENTS

1.2.1 Sequencing

Performance Verification Testing required by this Section must be preceded by successful and accepted "contractors field testing" or "start-up and start-up testing" of the control system to be tested.

1.2.2 Scheduling

Coordinate testing schedules with the Government and with work in other Sections performed on the components or systems to be tested.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-06 Test Reports

PVT Plan; G

PVT Phase I Report; G

PVT Phase II Report; G

SD-07 Certificates

Test Instrumentation Calibration Certificates; G

1.4 TEST EQUIPMENT

Provide all test equipment unless otherwise noted in the contract documents. Use only test equipment with current calibration traceable to the National Institute of Science and Technology (NIST). For each test instrument, submit Test Instrumentation Calibration Certificates demonstrating calibration traceable to NIST. Use test equipment and test methods such that the overall accuracy of the test method, including all test instrumentation and any errors inherent in the test procedure, is at least 50 percent better than the accuracy specified for the sensor. For example, if a temperature sensor has an accuracy requirement of plus or minus 1 degree Fahrenheit degree overall accuracy of the test method, must

be 0.5 degree Fahrenheit or better.

When validating sensor accuracy, the test instrument is treated as if it is perfectly accurate; that is, the measured value from the test instrument must lie within the bounds of the specified accuracy of the sensor. Expressed mathematically:

Given:

Sensor accuracy: Plus or minus X
Sensor reading: Y
Test equipment reading: Z
Where X, Y and Z are real numbers.

Then

Sensor passes if: $(Y-X) \leq Z \leq (Y+X)$
otherwise, sensor fails

PART 2 PRODUCTS

Not applicable

PART 3 EXECUTION

3.1 PERFORMANCE VERIFICATION TEST (PVT)

Perform a Performance Verification Test (PVT) to demonstrate that the installed control system meets all requirements of the project specifications. Coordinate scheduling of the PVT with the Government, and do not begin the PVT until the PVT Plan submittal is accepted.

3.1.1 PVT PLAN

Provide a PVT Plan including system documentation and PVT Procedures.

3.1.1.1 PVT Plan System Documentation

Include the following system documentation in the PVT Plan:

- a. Copies of the most recent as-built drawings for the system, including but not limited to one-line drawings and Points Schedules as specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC showing device address, point descriptions, network point names and types, hardware point types, settings and ranges including units.
- b. Copies of manufacturer's product data sheets when needed to demonstrate compliance with project requirements. In particular, provide data sheets showing that surge protection requirements have been met.
- c. Operation or user manuals for all software and all DDC Hardware to be tested.
- d. List of test equipment.

3.1.1.2 PVT Equipment List

Include in the PVT procedures a control system performance verification test equipment list that lists the equipment to be used during performance verification testing. For each piece of equipment include manufacturer name, model number, equipment function, the date of the latest

calibration, and the results of the latest calibration

3.1.1.3 PVT Procedures

Develop PVT procedures using the test procedures in this Section, modifying the procedures and adding tests as appropriate to develop procedures that test all requirements of the project specifications. The test procedures must consist of detailed instructions for test setup, execution, and evaluation of test results.

When developing additional procedures, provide the same information and fields as shown in the Test Template.

3.1.2 PVT Phases

Conduct PVT testing in two phases:

- I. Field testing for devices, components, subsystems and the overall system using the approved PVT Procedures.
- II. A one-week endurance test during which the system is operated continuously.

3.1.2.1 PVT Phase I (Field Tests)

Demonstrate compliance of the control system with the contract documents. Using test plans and procedures approved by the Government, demonstrate all physical and functional requirements of the project. Show, step-by-step, the actions and results demonstrating that the control systems fully and correctly implement the sequences of operation. PVT for surge protection is not required to include introducing a surge to the equipment; surge protection may instead be demonstrated through product documentation.

Do not start the performance verification test until after receipt of written permission by the Government, based on Government approval of the PVT Plan and Draft As-Builts and completion of balancing of the HVAC System. Do not conduct tests during scheduled seasonal off periods of base heating and cooling systems. At the completion PVT Phase I and in accordance with the project schedule and project sequencing provide a PVT Phase I Report documenting all PVT testing including all approved test procedures with test results indicated on the procedures, and a record of all actions taken to address PVT test failures.

3.1.2.2 PVT Phase II (Endurance Test)

Complete an endurance test as part of the PVT in which the system is operated continuously for one-week without failure. During the endurance test trend all points shown as requiring a trend on the Points Schedule for the entire duration of the endurance test. If insufficient buffer or storage capacity exists to trend the entire endurance test, offload trend logs during the course of the endurance test to ensure that no trend data is lost. If the control system specification includes bandwidth requirements for bandwidth usage on a non-IP network, measure and record the network bandwidth usage on each non-IP channel during the endurance test.

If the system experiences any failures during the endurance test portion of the PVT, repair the system and repeat the endurance test portion of the

PVT until the system operates continuously and without failure for the specified endurance test period. At the completion of PVT Phase II and in accordance with the project schedule and project sequencing provide a PVT Phase II Report documenting failures and repair actions taken during PVT Phase II.

3.1.2.2.1 Temporary Trending Capability

Unless trending capability exists, either within the building control system or through a connected Utility Monitoring and Control System (UMCS) Front End, temporarily install hardware on the building control network to perform trending during the endurance test as indicated. Remove the temporary hardware at the completion of all testing and commissioning activities.

3.2 FACTORY TEST

Perform a Factory Test to demonstrate the capability of the proposed control system solution to meet the requirements of project specifications. Coordinate scheduling of the Factory Test with the Government, and do not begin the Factory Test until the Factory Test Plan submittal is accepted.

3.2.1 Factory Test Setup

Design the Factory Test Setup to represent the system as it will be fielded and to demonstrate the capability of the system to meet the requirements of the project specification. At a minimum:

- a. Include at least one of each model of DDC hardware, instrumentation and control device to be used on the project.
- b. Include at least one network of each type to be used on the project.
- c. Include a programmable controller programmed as it will be installed, or, if no programmable controller is to be installed on the project, include a programmable controller with a sample application.
- d. Include sample hardware to provide a mock field control system for the front end to communicate with if the project requires a front end but does not require a field control system.

3.2.2 Factory Test Plan

Provide a Factory Test Plan documenting the test setup and procedures.

3.2.2.1 Factory Test Plan Setup Documentation

Include the following information, at a minimum, to document the factory test setup:

- a. System one-line block diagram of equipment used in the factory test identifying computers (servers and workstations), network hardware, DDC hardware, and other instrumentation including, but not limited to, sensors, actuators, test signal generators, and meters.
- b. System hardware description used in the factory test.
- c. System software description used in the factory test.

- d. Points Schedules for each controller showing the configuration to be used during the test. Points Schedules must be as specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.
- e. Required passwords for each operator access level.
- f. List of other test equipment.

3.2.2.2 Test Procedures

Develop factory test procedures using the Test Procedures in this Section, modifying the procedures and adding tests as appropriate to develop test procedures that test all requirements of the specification. The test procedures must consist of detailed instructions for test setup, execution, and evaluation of test results. Factory test procedures must include testing of surge protection by introducing a surge to the equipment and demonstrating that the equipment survives.

When developing additional procedures, provide the same information and fields as shown in the Test Template.

3.2.3 Factory Test Report

Upon completion of the Factory Test provide a complete test report, consisting of a short summary of the factory test, a copy of the Factory Test Plan, and copies of the executed test procedures separated by test. For each test, include date performed and identify the Government representative who witnessed and approved the test.

If a portion of any test failed, document the failure and corrective action.

3.2.4 Factory Test Execution

Conduct the Factory Test at a location and time approved by the Government. The Government will witness the factory test.

If the system fails a portion of a test, the Government will determine whether the entire test or only the portion that failed must be repeated.

3.3 TEST PROCEDURES

Develop test procedures using the template procedure in the Appendix. A test template and sample test procedures in electronic format are available at the Whole Building Design Guide page for this section: <https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-25-08-1> Refer to the Sample Test Procedures Table to view the existing sample tests.

Sample Test Procedures	
Test No.	Test Title
1	System Equipment Verification

Sample Test Procedures	
Test No.	Test Title
2	System Start-up
3	Monitoring and Control (M&C) Software Passwords
4	Graphic Display of Data
5	Graphic Navigation Scheme
6	Command Functions
7	Command Input Errors
8	Special Functions
9	Software Editing Tools
10	Scheduling
11	Alarm function
12	Trending
13	Demand Limiting
14	Report Generation
15	Uninterruptable Power Supply (UPS) Test
16	Routers and Repeaters
17	Gateways (Building Level)
18	Gateways (Device Level)
19	Local Display Panel (LDP)
20	Open Network Point Verification
21	Custom Test Template

APPENDIX A

TEST NUMBER: <TEST NUMBER>
TEST TITLE: <TEST TITLE>

OBJECTIVE: <STATE TEST OBJECTIVE>

INITIAL REQUIREMENTS/CONDITIONS

1. Submittals: <LIST REQUIRED SUBMITTALS>
2. Equipment: <LIST EQUIPMENT REQUIRED FOR TEST>
3. Reference Documentation: <LIST REQUIRED REFERENCE DOCUMENTATION>

Date of Test: _____
Time of Test: _____
Contractor's Representative: _____
Government's Representative: _____

Specification References for this verification:
<LIST SECTIONS REFERENCED FOR THIS TEST>

TEST PROCEDURES: <USE THE FOLLOWING FORMAT FOR TEST PROCEDURES, EXPAND AS NECESSARY TO CAPTURE ALL TEST ITEMS>

Item	Action	Expected Results	Approved
1			
2			
3			
4			

Item	Action	Expected Results	Approved
Notes:			

-- End of Section --

SECTION 25 10 10

UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION
02/19, CHG 1: 05/21

PART 1 GENERAL

1.1 SUMMARY

Provide a Utility Monitoring and Control System (UMCS) which performs supervisory monitoring and supervisory control of base-wide building control systems and utility control systems using one or more of: CEA-709.1-D (LonWorks) with LonWorks Network Services (LNS), ASHRAE 135 (BACnet), MODBUS Protocol, MODBUS TCP/IP, OPC DA, or the Niagara Framework with Fox protocol as indicated and shown. Integrate ASHRAE 135 (BACnet) field control systems installed per Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS as specified.

1.1.1 System Requirements

Provide a UMCS as specified and indicated, and in accordance with the following characteristics:

1.1.1.1 General System Requirements

- a. The system performs supervisory monitoring and control functions including but not limited to Scheduling, Alarm Handling, Trending, Overrides, Report Generation, and Electrical Demand Limiting as specified.
- b. The system includes a Graphical User Interface which allows for graphical navigation between systems, graphical representations of systems, access to real-time data for systems, ability to override points in a system, and access to all supervisory monitoring and control functions.
- c. All software used by the UMCS and all software used to install and configure the UMCS is licensed to and delivered to the installation.
- d. All necessary documentation, configuration information, configuration tools, programs, drivers, and other software is licensed to and otherwise remains with the Government such that the Government or their agents are able to repair, replace, upgrade, and expand the system without subsequent or future dependence on the Contractor. Software licenses must not require periodic fees and must be valid in perpetuity.
- e. Provide sufficient documentation and data, including rights to documentation and data, such that the Government or their agents can execute work to repair, replace, upgrade, and expand the system without subsequent or future dependence on the Contractor.
- f. The UMCS interfaces directly to ASHRAE 135, CEA-709.1-D, MODBUS Protocol, MODBUS TCP/IP, OPC DA, and Niagara Framework field control systems as specified and may interface to field control systems using other protocols via an M&C Software protocol driver or a Gateway.

- g. For UMCS systems with Monitoring and Control Software functionality implemented in Monitoring and Control (M&C) Controller Hardware, provide sufficient additional controller hardware to support the full capacity requirements as specified.

1.1.1.2 BACnet Requirements

- a. The UMCS must communicate using ASHRAE 135 Annex J over the Government furnished IP network as specified.
- b. All communication between the UMCS and ASHRAE 135 field control networks must be via the ASHRAE 135 protocol over the IP network.
- c. All communication between the M&C Software and the field control system devices must be via standard ASHRAE 135 services other than PrivateTransfer and ConfirmedPrivateTransfer except as follows:
 - (1) PrivateTransfer and ConfirmedPrivateTransfer may be used for device configuration and device programming.
 - (2) PrivateTransfer and ConfirmedPrivateTransfer may be used for communication between the M&C Software and the field control system if and only if both the M&C Software and the field control system devices automatically (without requiring reconfiguration) revert to the use of other standard ASHRAE 135 services when one of the components is modified or replaced.

1.1.1.3 Modbus Requirements

The UMCS must communicate using MODBUS Protocol, MODBUS TCP/IP over the Government furnished IP network as specified.

Modbus communications must support all of the following Modbus data types:

- a. The four standard data types defined by MODBUS Protocol, MODBUS TCP/IP: Discrete Inputs, Coils, Input Registers, and Holding Registers. (Note that these four data types are included in the MODBUS Protocol, MODBUS TCP/IP standard. The remaining data types indicated in this Section are not included in the MODBUS Protocol, MODBUS TCP/IP standard but are defined by this Section to provide a standard for communication between systems.)
- b. Character: Character data using a single Input Register or single Holding Register where that Modbus register is interpreted as two 8 bit ISO 8859-1 characters, with the low order bits representing the right-hand character.
- c. Floating Point: Floating point data using two consecutive Input Registers or two consecutive Holding Registers where the resulting 32 bits are interpreted as a Binary32 (Single Precision Floating point) number as specified in IEEE 754. Use the first Register for the higher 16 bits, and the second Register for the lower 16 bits.
- d. Integer Date: Date data using three consecutive Input Registers or three consecutive Holding Registers where the resulting 48 bits are interpreted as a 48-bit unsigned big-endian integer. The value is the

number of milliseconds, not including leap seconds, from 1970-01-01T00:00:00.000 (12AM, January 1, 1970). Use the first Register for the highest 16 bits and the third Register for the lowest 16 bits.

- e. Character Date: Date data using the format specified in ISO 8601 of "YYYY-MM-DDTHH:MM:SS.SSS", where the individual characters are formatted as specified for character data.

1.1.1.4 OPC Requirements

The UMCS must communicate using OPC DA over the Government furnished IP network as shown and specified.

1.1.2 Symbols, Definition and Abbreviations

Use symbols, definitions, and engineering unit abbreviations indicated in the contract drawings for displays, submittals and reports. For symbols, definitions and abbreviations not in the contract drawings use terms conforming at a minimum to IEEE Stds Dictionary and the ASHRAE FUN IP, as applicable.

1.1.3 System Units and Accuracy

Use English (inch-pound) units for displays, print-outs and calculations. Perform calculations with an accuracy of at least three significant figures. For displays and printouts present values to at least three significant figures.

1.1.4 Data Packages/Submittals Requirements

Technical data packages consisting of computer software and technical data (meaning technical data which relates to computer software) which are specifically identified in this project and which may be defined/required in other specifications must be delivered strictly in accordance with the CONTRACT CLAUSES and in accordance with the Contract Data Requirements List, DD Form 1423. Data delivered must be identified by reference to the particular specification paragraph against which it is furnished. All submittals not specified as technical data packages are considered shop drawings under the Federal Acquisition Regulation Supplement (FARS) and must contain no proprietary information and must be delivered with unrestricted rights.

1.2 RELATED SECTIONS

Cybersecurity requirements related to this Section are specified in a separate cybersecurity specification derived from UFGS 25 05 11. Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS specifies cybersecurity requirements related to this Section.

1.3 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI INCITS 154

(1988; R 2004) Office Machines and

Supplies - Alphanumeric Machines -
Keyboard Arrangement

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING
ENGINEERS (ASHRAE)

ASHRAE 135 (2020; Interpretation 1-8 2021; Errata 1-2
2021; Addenda CD 2021; Addenda BV-CE 2022;
Interpretation 9-12 2022; Interpretation
13-24 2023; Addenda BV-CF 2023; Errata 3
2023) BACnet-A Data Communication Protocol
for Building Automation and Control
Networks

ASHRAE FUN IP (2021) Fundamentals Handbook, I-P Edition

CONSUMER ELECTRONICS ASSOCIATION (CEA)

CEA-709.1-D (2014) Control Network Protocol
Specification

CEA-709.3 (1999; R 2015) Free-Topology Twisted-Pair
Channel Specification

CEA-852-C (2014) Tunneling Device Area Network
Protocols Over Internet Protocol Channels

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 754 (2008) Floating-Point Arithmetic - IEEE
Computer Society

IEEE 802.11 (2020; BD 2022) Information
Technology-Telecommunications and
Information Exchange Between Systems Local
and Metropolitan Area Networks - Specific
Requirements Part 11: Wireless LAN Medium
Access Control (MAC) and Physical Layer
(PHY) Specifications Amendment 3: Wake-Up
Radio Operation

IEEE 1815 (2015; CORR 2016) Exchanging Information
Between Networks Implementing IEC 61850
and IEEE Std 1815 Distributed Network
Protocol (DNP3)

IEEE C62.41 (1991; R 1995) Recommended Practice on
Surge Voltages in Low-Voltage AC Power
Circuits

IEEE Stds Dictionary (2009) IEEE Standards Dictionary: Glossary
of Terms & Definitions

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 8601 (2004) Data Elements and Interchange
Formats - Information Interchange -
Representation of Dates and Times

ISO 8859-1 (1998) Information Technology - 8-Bit
Single-Byte Coded Graphic Character Sets -
Part 1: Latin Alphabet No. 1

INTERNET ENGINEERING TASK FORCE (IETF)

IETF RFC 4361 (2006) Node-specific Client Identifiers
for Dynamic Host Configuration Protocol
Version Four (DHCPv4)

IETF RFC 7465 (2015) Prohibiting RC4 Cipher Suites

RFC 821 (2001) Simple Mail Transfer Protocol (SMTP)

LONMARK INTERNATIONAL (LonMark)

LonMark Interoperability Guide (2005) LonMark Application-Layer
Interoperability Guide and LonMark Layer
1-6 Interoperability Guide; Version 3.4

LonMark SNVT List (2014) LonMark SNVT Master List; Version 15

LonMark XIF Guide (2001) LonMark External Interface File
Reference Guide; Revision 4.402

MODBUS ORGANIZATION, INC (MODBUS)

MODBUS Protocol (2012) Modbus Application Protocol
Specification; Version 1.1b3

MODBUS TCP/IP (2006) Modbus Messaging on TCP/IP
Implementation Guide; Version V1.0b

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250 (2020) Enclosures for Electrical Equipment
(1000 Volts Maximum)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National
Electrical Code

NFPA 262 (2023) Standard Method of Test for Flame
Travel and Smoke of Wires and Cables for
Use in Air-Handling Spaces

OPC FOUNDATION (OPC)

OPC DA (Ver 3.0; Errata) OPC Data Access (DA)

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-568.1 (2020e) Commercial Building
Telecommunications Infrastructure Standard

TIA-606 (2021d) Administration Standard for
Telecommunications Infrastructure

TIA-607 (2019d) Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises

TRIDIUM, INC (TRIDIUM)

Niagara Framework (2021) NiagaraAX User's Guide

U.S. FEDERAL COMMUNICATIONS COMMISSION (FCC)

FCC EMC (2002) FCC Electromagnetic Compliance Requirements

FCC Part 15 Radio Frequency Devices (47 CFR 15)

UNDERWRITERS LABORATORIES (UL)

UL 1778 (2014; Reprint Apr 2023) UL Standard for Safety Uninterruptible Power Systems

UL 60950 (2000; Reprint Oct 2007) Safety of Information Technology Equipment

1.4 DEFINITIONS

The following list of definitions may contain terms not found elsewhere in this Section but are included here for completeness. Some terms are followed with a protocol reference in parenthesis indicating to which protocol the term and definition applies. Inclusion of protocol-specific definitions does not create a requirement to support that protocol, nor does it relax any requirements to support specific protocols as indicated elsewhere in this section.

1.4.1 Alarm Generation

The process of comparing a point value (the point being alarmed) with a pre-defined alarm condition (e.g. a High Limit) and performing some action based on the result of the comparison.

1.4.2 Alarm Handling

see Alarm Routing

1.4.3 Alarm Routing

Alarm routing is M&C software functionality that starts with a notification that an alarm exists (typically as the output of an Alarm Generation process) and sends a specific message to a specific alarm recipient or device.

1.4.4 Application Generic Controller (AGC)(LonWorks)

A device that is furnished with a (limited) pre-established application that also has the capability of being programmed. Further, the ProgramID and XIF file of the device are fixed. The programming capability of an AGC may be less flexible than that of a General Purpose Programmable Controller (GPPC).

1.4.5 Application Specific Controller (ASC)(LonWorks)

A device that is furnished with a pre-established built in application that is configurable but not re-programmable. An ASC has a fixed factory-installed application program (i.e Program ID) with configurable settings.

1.4.6 BACnet (BACnet)

The term BACnet is used in two ways. First meaning the BACnet Protocol Standard - the communication requirements as defined by ASHRAE 135 including all annexes and addenda. The second to refer to the overall technology related to the ASHRAE 135 protocol.

1.4.7 BACnet Advanced Application Controller (B-AAC)(BACnet)

A hardware device BTL Listed as a B-AAC. A control device which contains BIBBs in support of scheduling and alarming but otherwise has limited resources relative to a B-BC. It may be intended for specific applications and supports some degree of programmability.

1.4.8 BACnet Advanced Operator Workstation (B-AWS)(BACnet)

Monitoring and Control (M&C) Software BTL Listed as an Advanced Operator Workstation and includes the ability to manage scheduling, alarming and trending in an open manner. The B-AWS is the advanced operator's window into a BACnet system. It is primarily used to monitor the performance of a system and to modify parameters that affect the operation of a system.

1.4.9 BACnet Application Specific Controller (B-ASC)(BACnet)

A hardware device BTL Listed as a B-ASC. A controller with limited resources relative to a B-AAC. It is intended for use in a specific application and supports limited programmability.

1.4.10 BACnet Building Controller (B-BC)(BACnet)

A hardware device BTL Listed as a B-BC. A general-purpose, field-programmable device capable of carrying out a variety of building automation and control tasks including control and monitoring via direct digital control (DDC) of specific systems and data storage for trend information, time schedules, and alarm data. Like the other BTL Listed controller types (B-AAC, B-ASC etc.) a B-BC device is required to support the server ("B") side of the ReadProperty and WriteProperty services, but unlike the other controller types it is also required to support the client ("A") side of these services. Communication between controllers requires that one of them support the client side and the other support the server side, so a B-BC is often used when communication between controllers is needed.

1.4.11 BACnet Internetwork (BACnet)

Two or more BACnet networks connected with BACnet routers. In a BACnet Internetwork, there exists only one message path between devices.

1.4.12 BACnet Interoperability Building Blocks (BIBBs) (BACnet)

A BIBB is a collection of one or more BACnet services intended to define a higher level of interoperability. BIBBs are combined to build the BACnet

functional requirements for a device in a specification. Some BIBBs define additional requirements (beyond requiring support for specific services) in order to achieve a level of interoperability. For example, the BIBB DS-V-A (Data Sharing-View-A), which would typically be used by an M&C client, not only requires the client to support the ReadProperty Service, but also provides a list of data types (Object / Properties) which the client must be able to interpret and display for the user.

1.4.13 BACnet Operator Display (B-OD)(BACnet)

A hardware device BTL Listed as a B-OD. A basic operator interface with limited capabilities relative to a B-OWS. It is not intended to perform direct digital control. The B-OD profile could be used for wall-mounted LCD devices, displays affixed to BACnet devices; hand-held terminals or other very simple user interfaces.

1.4.14 BACnet Operator Workstation (B-OWS)(BACnet)

Monitoring and Control (M&C) Software BTL Listed as a B-OWS. An operator interface with limited capabilities relative to a B-AWS. The B-OWS is used for monitoring and basic control of a system, but differs from a B-AWS in that it does not support configuration activities, nor does it provide advanced troubleshooting capabilities.

1.4.15 BACnet Smart Actuator (B-SA)(BACnet)

A hardware device BTL Listed as a B-SA. A simple control output device with limited resources; it is intended for specific applications.

1.4.16 BACnet Smart Sensor (B-SS)(BACnet)

A hardware device BTL Listed as a B-SS. A simple sensing device with very limited resources.

1.4.17 BACnet Testing Laboratories (BTL)(BACnet)

Established by BACnet International to support compliance testing and interoperability testing activities and consists of BTL Manager and the BTL Working Group (BTL-WG). BTL also publishes Implementation Guidelines.

1.4.18 BACnet Testing Laboratories (BTL) Listed (BACnet)

A device that has been certified by BACnet® Testing Laboratory. Devices may be certified to a specific device profile, in which case the certification indicates that the device supports the required capabilities for that profile, or may be certified as "other".

1.4.19 Binary

A two-state system or signal; for example one where an "ON" condition is represented by a high signal level and an "OFF" condition is represented by a low signal level. 'Digital' is sometimes used interchangeably with 'binary'.

1.4.20 Binding (LonWorks)

The act of establishing communications between CEA-709.1-D devices by associating the output of a device to the input of another so that information is automatically (and regularly) sent without being requested

by the recipient.

1.4.21 Broadcast

Unlike most messages, which are intended for a specific recipient device, a broadcast message is intended for all devices on the network.

1.4.22 Building Control Network (BCN)

The network used by the Building Control System. Typically the BCN is a BACnet ASHRAE 135 or LonWorks CEA-709.1-D network installed by the building control system contractor.

1.4.23 Building Control System (BCS)

One type of Field Control System. A control system for building electrical and mechanical systems, typically HVAC (including central plants) and lighting. A BCS generally uses Direct Digital Control (DDC) Hardware and generally does NOT include its own local front end.

1.4.24 Building Point of Connection (BPOC)

A FPOC for a Building Control System. (This term is being phased out of use in preference for FPOC but is still used in some specifications and criteria. When it was used, it typically referred to a piece of control hardware. The current FPOC definition typically refers instead to IT hardware)

1.4.25 Channel (LonWorks)

A portion of the control network consisting of one or more segments connected by repeaters. Channels are separated by routers. The device quantity limitation is dependent on the topology/media and device type. For example, a TP/FT-10 network with locally powered devices is limited to 128 devices per channel.

1.4.26 Commandable (BACnet)

A point (Object) is commandable if its Present_Value Property is writable and it supports the optional Priority_Array Property. This functionality is useful for Overrides.

1.4.27 Configuration Property (LonWorks)

Controller parameter used by the application which is usually set during installation/testing and seldom changed. For example, the P and I settings of a P-I control loop. Also see 'Standard Configuration Property Type (SCPT)'

1.4.28 Control Logic Diagram

A graphical representation of control logic for multiple processes that make up a system.

1.4.29 Device Object (BACnet)

Every BACnet device requires one Device Object, whose properties represent the network visible properties of that device. Every Device Object requires a unique Object_Identifier number on the BACnet Internetwork.

This number is often referred to as the device instance or device ID.

1.4.30 Explicit Messaging (LonWorks)

A non-standard and often vendor (application) specific method of communication between devices.

1.4.31 External Interface File (XIF) (LonWorks)

A file which documents a device's external interface, specifically the number and types of LonMark objects, the number, types, directions, and connection attributes of network variables, and the number of message tags.

1.4.32 Field Point Of Connection (FPOC)

The FPOC is part of the UMCS IP network and acts as the point of connection between the UMCS IP Network and the field control IP network. The FPOC is an IT device such as a switch, IP router, or firewall, typically managed by the site IT staff. (Note that the field control IP network may consist of a single IP device, or that integration may require installation of a field control network IP device.)

1.4.33 Field Control Network

The network used by a field control system.

1.4.34 Field Control System (FCS)

A building control system or utility control system.

1.4.35 Fox Protocol (Niagara Framework)

The protocol used for communication between components in the Niagara Framework. By default, Fox uses TCP port 1911

1.4.36 Functional Profile (LonWorks)

A standard description, defined by LonMark International, of a LonMark Object used to classify and certify devices.

1.4.37 Gateway

A device that translates from one protocol to another. Devices that change only the transport mechanism of the protocol - "translating" from LonWorks over TP/FT-10 to LonWorks over IP for example - are not gateways as the underlying protocol (data format) does not change. Gateways are also called Communications Bridges or Protocol Translators.

1.4.38 General Purpose Programmable Controller (GPPC) (LonWorks)

Unlike an ASC or AGC, a GPPC is not furnished with a fixed application program and does not have a fixed ProgramID or XIF file. A GPPC can be (re-)programmed, usually using vendor-supplied software. When a change to the program affects the external interface (and the XIF file) the ProgramID will change.

1.4.39 Internetwork (BACnet)

See BACnet Internetwork.

1.4.40 JACE (Niagara Framework)

Java Application Control Engine. See Niagara Framework Supervisory Gateway

1.4.41 LonMark Object (LonWorks)

A collection of network variables, configuration properties, and associated behavior defined by LonMark International and described by a Functional Profile. It defines how information is exchanged between devices on a network (inputs from and outputs to the network).

1.4.42 LNS Plug-in (LonWorks)

Software which runs in an LNS compatible software tool, typically a network configuration tool. Device configuration plug-ins provide a 'user friendly' method to edit a device's configuration properties.

1.4.43 LonMark (LonWorks)

See LonMark International. Also, a certification issued by LonMark International to CEA-709.1-D devices.

1.4.44 LonMark International (LonWorks)

Standards committee consisting of independent product developers, system integrators and end users dedicated to determining and maintaining the interoperability guidelines for LonWorks. Maintains guidelines for the interoperability of CEA-709.1-D devices and issues the LonMark Certification for CEA-709.1-D devices.

1.4.45 LonWorks (LonWorks)

The term used to refer to the overall technology related to the CEA-709.1-D protocol (sometimes called "LonTalk"), including the protocol itself, network management, interoperability guidelines and products.

1.4.46 LonWorks Network Services (LNS) (LonWorks)

A network management and database standard for CEA-709.1-D devices.

1.4.47 LonWorks Network Services (LNS) Database (LonWorks)

The standard database created and used by LonWorks Network Services (LNS) compatible tools, such as LNS Network Configuration tools.

1.4.48 Modbus

A basic protocol for control network communications generally used in utility control systems. The Modbus protocol standard is maintained by The Modbus Organization.

1.4.49 Master-Slave/Token Passing (MS/TP)(BACnet)

Data link protocol as defined by the BACnet standard. Multiple speeds (data rates) are permitted by the BACnet MS/TP standard.

1.4.50 Monitoring and Control (M&C) Software

The UMCS 'front end' software which performs supervisory functions such as alarm handling, scheduling and data logging and provides a user interface for monitoring the system and configuring these functions.

1.4.51 Network (BACnet)

In BACnet, a portion of the control internetwork consisting of one or more segments of the same media connected by repeaters. Networks are separated by routers.

1.4.52 Network Variable (LonWorks)

See 'Standard Network Variable Type (SNVT)'.

1.4.53 Network Configuration Tool (LonWorks)

The software used to configure the control network and set device configuration properties. This software creates and modifies the control network database (LNS Database).

1.4.54 Niagara Framework

A set of hardware and software specifications for building and utility control owned by Tridium Inc. and licensed to multiple vendors. The Framework consists of front end (M&C) software, web based clients, field level control hardware, and engineering tools. While the Niagara Framework is not adopted by a recognized standards body and does not use an open licensing model, it is sufficiently well-supported by multiple HVAC vendors to be considered a de-facto Open Standard.

1.4.55 Niagara Framework Supervisory Gateway (Niagara Framework)

DDC Hardware component of the Niagara Framework. A typical Niagara architecture has Niagara specific supervisory gateways at the IP level and other (non-Niagara specific) controllers on field networks (TP/FT-10, MS/TP, etc.) beneath the Niagara supervisory gateways. The Niagara specific controllers function as a gateway between the Niagara framework protocol (Fox) and the field network beneath. These supervisory gateways may also be used as general purpose controllers and also have the capability to provide a web-browser based user interface.

Note that different vendors refer to this component by different names. The most common name is "JACE"; other names include "EC-BOS", "FX-40", and "UNC".

1.4.56 Node (LonWorks)

A device that communicates using the CEA-709.1-D protocol and is connected to a CEA-709.1-D network.

1.4.57 Node Address (LonWorks)

The logical address of a node on the network, consisting of a Domain number, Subnet number and Node number. Note that the "Node number" portion of the address is the number assigned to the device during installation and is unique within a subnet. This is not the factory-set unique Node ID (see Node ID).

1.4.58 Node ID (LonWorks)

A unique 48-bit identifier assigned (at the factory) to each CEA-709.1-D device. Sometimes called the Neuron ID.

1.4.59 Object (BACnet)

A BACnet Object. The concept of organizing BACnet information into standard components with various associated Properties. Examples include Analog Input objects and Binary Output objects.

1.4.60 Override

To change the value of a point outside of the normal sequence of operation where this change has priority over the sequence. An override can be accomplished in one of two ways: the point itself may be Commandable and written to with a priority or there may be a separate point on the controller for the express purpose of implementing the override.

Typically this override is from the Utility Monitoring and Control System (UMCS) Monitoring and Control (M&C) Software. Note that this definition is not standard throughout industry.

1.4.61 Point, Calculated

A value within the M&C Software that is not a network point but has been calculated by logic within the software based on the value of network points or other calculated points. Calculated points are sometimes called virtual points or internal points.

1.4.62 Point, Network

A value that the M&C Software reads from or writes to a field control network.

1.4.63 Polling

A requested transmission of data between devices, rather than an unrequested transmission such as Change-Of-Value (COV) or Binding where data is automatically transmitted under certain conditions.

1.4.64 Program ID (LonWorks)

An identifier (number) stored in the device (usually EEPROM) that identifies the node manufacturer, functionality of device (application & sequence), transceiver used, and intended device usage.

1.4.65 Property (BACnet)

A BACnet Property - a data element associated with an Object. Different Objects have different Properties, for example an Analog Input Object has a Present_Value Property (which provides the value of the underlying hardware analog input), a High_Limit Property (which contains a high limit for alarming), as well as other properties.

1.4.66 Protocol Implementation Conformance Statement (PICS)(BACnet)

A document, created by the manufacturer of a device, which describes which

options of the BACnet standard are implemented by a given device.

1.4.67 Repeater

A device that connects two control network segments and retransmits all information received on one side onto the other.

1.4.68 Router (LonWorks)

A device that connects two channels and controls traffic between the channels by retransmitting signals received from one subnet onto the other based on the signal destination. Routers are used to subdivide a control network and to control bandwidth usage.

1.4.69 Router (BACnet)

A device that connects two or more BACnet networks and controls traffic between the networks by retransmitting signals received from one network onto another based on the signal destination. Routers are used to subdivide an internetwork and to control bandwidth usage.

1.4.70 Segment

A 'single' section of a control network that contains no repeaters or routers. There is generally a limit on the number of devices on a segment, and this limit is dependent on the topology/media and device type. For example, a TP/FT-10 segment with locally powered devices is limited to 64 devices, and a BACnet MS/TP segment is limited to 32 devices.

1.4.71 Service (BACnet)

A BACnet Service. A defined method for sending a specific type of data between devices. Services are always defined in a Client-Server manner, with a Client initiating a Service request and a Server Executing the Service. Some examples are ReadProperty (a client requests a data value from a server), WriteProperty (a client writes a data value to a server), and CreateObject (a client requests that a server create a new object within the server device).

1.4.72 Service Pin (LonWorks)

A hardware push-button on a device which causes the device to broadcast a message containing its Node ID and Program ID. This broadcast can also be initiated via software.

1.4.73 Standard BACnet Object/Property/Service (BACnet)

BACnet Objects, Properties, or Services that are standard Objects, Properties, or Services enumerated and defined in ASHRAE 135. Clause 23 of ASHRAE 135 defines methods to extend ASHRAE 135 to non-standard or proprietary information. Standard BACnet Objects/Properties/Services specifically exclude any vendor specific extensions.

1.4.74 Standard Configuration Property Type (SCPT) (LonWorks)

Pronounced 'skip-it'. A standard format type (maintained by LonMark International) for Configuration Properties.

1.4.75 Standard Network Variable Type (SNVT) (LonWorks)

Pronounced 'snivet'. A standard format type (maintained by LonMark International) used to define data information transmitted and received by the individual nodes. The term SNVT is used in two ways. Technically it is the acronym for Standard Network Variable Type, and is sometimes used in this manner. However, it is often used to indicate the network variable itself (i.e. it can mean "a network variable of a standard network variable type"). In general, the intended meaning should be clear from the context.

1.4.76 Subnet (LonWorks)

Consists of a logical grouping of up to 127 nodes, where the logical grouping is defined by node addressing. Each subnet is assigned a number which is unique within the Domain. See also Node Address.

1.4.77 Supervisory Controller

A controller implementing a combination of supervisory logic (global control strategies or optimization strategies), scheduling, alarming, event management, trending, web services or network management. Note this is defined by use; many supervisory controllers have the capability to also directly control equipment.

1.4.78 Supervisory Gateway

A device that is both a supervisory controller and a gateway.

1.4.79 TP/FT-10 (LonWorks)

A Free Topology Twisted Pair network (at 78 kbps) defined by CEA-709.3. This is the most common media type for a CEA-709.1-D control network.

1.4.80 TP/XF-1250 (LonWorks)

A high speed (1.25 Mbps) twisted pair, doubly-terminated bus network defined by the LonMark Interoperability Guidelines. This media is typically used only as a backbone media to connect multiple TP/FT-10 networks.

1.4.81 UMCS Network

An IP network connecting multiple field control systems to the Monitoring and Control Software using one or more of: LonWorks (CEA-709.1-D and CEA-852-C), BACnet (ASHRAE 135 Annex J), MODBUS Protocol, MODBUS TCP/IP or OPC DA.

1.4.82 User-defined Configuration Property Type (UCPT) (LonWorks)

Pronounced 'u-keep-it'. A Configuration Property format type that is defined by the device manufacturer.

1.4.83 User-defined Network Variable Type (UNVT) (LonWorks)

A network variable format defined by the device manufacturer. Note that UNVTs create non-standard communications (other vendor's devices may not correctly interpret it) and may close the system and therefore are not permitted by this specification.

1.4.84 Utility Control System (UCS)

One type of field control system. Used for control of utility systems such as an electrical substation, sanitary sewer lift station, water pump station, etc. Building controls are excluded from a UCS, however it is possible to have a Utility Control System and a Building Control System in the same facility, and for those systems to share components such as the FPOC. A UCS may include its own local front-end.

1.5 SUBMITTALS

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES and TABLE 1: PROJECT SEQUENCING:

SD-02 Shop Drawings

UMCS Contractor Design Drawings; G

UMCS Contractor Design Drawings as a single complete package: 2 hard copies and 1 copies on CDROM. Submit hardcopy drawings on ISO A1 34 by 22 inches sheets, and electronic drawings in both PDF and AutoCAD format.

Draft As-Built Drawings; G

Draft As-Built Drawings as a single complete package: 2 hard copies and 1 copies on CDROM. Submit hardcopy drawings must on ISO A1 34 by 22 inches sheets, and electronic drawings in both PDF and AutoCAD format.

Final As-Built Drawings; G

Final As-Built Drawings as a single complete package: 2 hard copies and 1 copies on CDROM. Submit hardcopy drawings on ISO A1 34 by 22 inches sheets, and electronic drawings in both PDF and AutoCAD format.

SD-03 Product Data

Product Data Sheets; G

Computer Software; G

The most recent versions of all computer software provided under this specification delivered as a Technical Data Package. Submit the user manuals for all software delivered for this project with the software.

Enclosure Keys; G

SD-05 Design Data

UMCS IP Network Bandwidth Usage Estimate; G

Four copies of the UMCS IP Network Bandwidth Usage Estimate.

SD-06 Test Reports

Pre-Construction QC Checklist; G

Four copies of the Pre-Construction QC Checklist.

Post-Construction QC Checklist; G

Four copies of the Post-Construction QC Checklist.
Existing Conditions Report; G

Four copies of the Existing Conditions Report.

Start-Up and Start-Up Testing Report; G

Four copies of the Start-Up and Start-Up Testing Report. The Start-Up and Testing report may be submitted as a Technical Data Package.

PVT Phase I Procedures; G

Four copies of the PVT Phase I Procedures. The PVT Procedures may be submitted as a Technical Data Package.

PVT Phase I Report; G

Four copies of the PVT Phase I Report. The PVT Phase I Report may be submitted as a Technical Data Package.

PVT Phase II Report; G

Four copies of the PVT Phase II Report. The PVT Phase II Report may be submitted as a Technical Data Package.

SD-10 Operation and Maintenance Data

Operation and Maintenance (O&M) Instructions; G

Four bound O&M Instructions and 2 copies of the Instructions in PDF format on optical disc. Index and tab bound instructions. Submit instructions in PDF form as a single PDF file, or as multiple PDF files with a PDF file table of contents containing links to the other files. O&M Instructions may be submitted as a Technical Data Package.

Preventive Maintenance Work Plan; G

Four copies of the Preventive Maintenance Work Plan. The Preventive Maintenance Work Plan may be submitted as a Technical Data Package.

Basic Training Documentation; G

Training manuals for Basic Training delivered for each trainee on the Course Attendance List with two additional copies delivered for archival at the project site. Submit two copies of the Course Attendance List with the archival copies. The Basic Training Documentation may be submitted as a Technical Data Package.

Advanced Training Documentation; G

One set of training manuals delivered for each trainee on the Course Attendance List with two additional copies delivered for archival at the project site. Submit two copies of the Course Attendance List with the archival copies. The Advanced Training Documentation may be submitted as a Technical Data Package.

Refresher Training Documentation; G

One set of training manuals delivered for each trainee on the Course Attendance List with two additional copies delivered for archival at the project site. Submit two copies of the Course Attendance List with the archival copies. The Refresher Training Documentation may be submitted as a Technical Data Package.

SD-11 Closeout Submittals

Closeout QC Checklist; G

Four copies of the Closeout QC Checklist.

1.6 PROJECT SEQUENCING

TABLE I: PROJECT SEQUENCING specifies the sequencing of submittals as specified in paragraph SUBMITTALS (denoted by an 'S' in the 'TYPE' column) and activities as specified in PART 3 EXECUTION (denoted by an 'E' in the 'TYPE' column).

1.6.1 Sequencing for Submittals

The sequencing specified for submittals is the deadline by which the submittal must be initially submitted to the Government. Following submission there will be a Government review period as specified in Section 01 33 00 SUBMITTAL PROCEDURES. If the submittal is not accepted by the Government, revise the submittal and resubmit it to the Government within 14 days of notification that the submittal has been rejected. Upon re-submittal there will be an additional Government review period. If the submittal is not accepted the process repeats until the submittal is accepted by the Government.

1.6.2 Sequencing for Activities

The sequencing specified for activities indicates the earliest the activity may begin.

1.6.3 Abbreviations

In TABLE I the abbreviation AAO is used for 'after approval of' and 'ACO' is used for 'after completion of'.

TABLE I. PROJECT SEQUENCING

ITEM	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY or DEADLINE FOR SUBMITTAL)
1		Notice to proceed	
2	S	Existing Conditions Report	14 days after #1
3	S	Design Drawings	14 days after #1
4	S	Product Data Sheets	14 days after #1
5	S	UMCS IP Network Bandwidth Usage Estimate	14 days after #1
6	S	Pre-construction QC Checklist	14 days after #1
7	E	Install UMCS	AAO #2 thru #6
8	E	Start-Up and Start-Up Testing	ACO #7
9	S	Post-Construction QC Checklist	14 days ACO #8
10	S	Computer Software	14 days ACO #8
11	S	Start-Up and Start-Up Testing Report	14 days ACO #8
12	S	Draft As-Built Drawings	14 days ACO #8
13	S	PVT Phase I Procedures	14 days before scheduled start of #14 and AAO #11
14	E	PVT Phase I	AAO #13 and #12
15	S	PVT Phase I Report	14 days ACO #14
16	S	Preventive Maintenance Work Plan	AAO #11
17	S	O&M Instructions	AAO #11
18	S	Basic Training Documentation	AAO #11 and 14 days before scheduled start of #19

TABLE I. PROJECT SEQUENCING

ITEM	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY or DEADLINE FOR SUBMITTAL)
19	E	Basic Training (PVT Phase II)	AAO #16, #17 and #18
20	S	PVT Phase II Report	14 days ACO #19
21	S	Final As-Built Drawings	14 days AAO #20
22	S	Advanced Training Documentation	14 days before schedule start of #23 and AAO #18
23	E	Advanced Training	ACO #19, 14 days AAO #22, and no later than 60 days ACO #19
24	S	Refresher Training Documentation	14 days before #25 and AAO #18 and #22
25	E	Refresher Training	between 14 and 14 days ACO #19 and AAO #24
26	S	Closeout QC Checklist	ACO #23

1.7 QUALITY CONTROL (QC) CHECKLISTS

The Contractor's Chief Quality Control (QC) Representative must complete the QC Checklist in APPENDIX A, and must submit the Pre-Construction QC Checklist, Post-Construction QC Checklist and Closeout QC Checklist as specified. The QC Representative must verify each item in the Checklist and initial in the provided area to indicate that the requirement has been met. The QC Representative must sign and date the Checklist prior to submission to the Government.

1.8 OPERATION AND MAINTENANCE (O&M) INSTRUCTIONS

Provide UMCS Operation and Maintenance Instructions which include:

- a. Procedures for the UMCS system start-up, operation and shut-down.
- b. Final As-Built drawings.
- c. Routine maintenance checklist, arranged in a columnar format: The first column listing all installed devices, the second column stating the maintenance activity or stating that no maintenance required, the third column stating the frequency of the maintenance activity, and the fourth column providing any additional comments or reference.
- d. Qualified service organization list including points of contact with phone numbers.

- e. Start-Up and Start-Up Testing Report.
- f. Performance Verification Test (PVT) Procedures and Reports.

PART 2 PRODUCTS

2.1 EQUIPMENT REQUIREMENTS

2.1.1 Product Certifications

For computing devices, as defined in FCC Part 15, supplied as part of the UMCS provide devices which are certified to comply with the requirements of Class B computing devices.

2.1.2 Product Sourcing

For units of the same type of equipment, provide products of a single manufacturer. For each major component of equipment provide equipment with the manufacturer's name and the model and serial number in a conspicuous place. For materials and equipment, provide new standard unmodified products of a manufacturer regularly engaged in the manufacturing of such products.

2.1.3 General Requirements

Provide components that meet the following requirements:

- a. Portions of the data communications equipment system installed in unconditioned spaces must operate properly in an environment with ambient temperatures between 32 and 120 degrees F and ambient relative humidity between 10 percent and 90 percent noncondensing.
- b. Components must accept 100 to 125 volts AC (Vac), 60 Hz, single phase, three wire with a three-pronged, dedicated circuit outlet or be provided with a transformer to meet the component's power requirements.
- c. The equipment must meet the requirements of NFPA 70, UL 60950, NFPA 262, FCC EMC, and FCC Part 15.

2.1.4 Nameplates

Provide nameplates of laminated plastic identifying the function, network address, if applicable, and identifier of the device. Laminated plastic must be at least 0.125 inch thick, white with black center core. Nameplates must be a minimum of 1 by 3 inch with minimum 0.25 inch high engraved block lettering.

2.1.5 Product Data Sheets

For all products (equipment) specified in PART 2 and supplied under this contract, submit copies of all manufacturer catalog cuts and specification sheets to indicate conformance to product requirements. For Monitoring and Control (M&C) Software also include the PICS verifying BTL Listing as a B-AWS.

2.2 CONTROL HARDWARE

2.2.1 Control Protocol Routers

2.2.1.1 LonWorks/IP Router

Provide LonWorks/IP Routers which perform layer 3 routing of CEA-709.1-D packets over an IP network in accordance with CEA-852-C. The router must provide the appropriate connection to the IP network and connections to the CEA-709.3 TP/FT-10 or TP/XF-1250 network. LonWorks/IP Routers must support the Dynamic Host Configuration Protocol (DHCP; IETF RFC 4361) for IP configuration and the use of an CEA-852-C Configuration Server (for CEA-852-C configuration), but must not rely on these services for configuration. LonWorks/IP Routers must be capable of manual configuration via a console RS-232 port.

2.2.1.2 BACnet/IP Router

Provide BACnet/IP Routers which perform layer 3 routing of ASHRAE 135 packets over an IP network in accordance with ASHRAE 135 Annex J and Clause 6. The router must provide the appropriate connection to the IP network and connections to a ASHRAE 135 MS/TP network. Devices used as BACnet/IP Routers must be BTL Listed and must support the Network Management-Router Configuration-B (NM-RC-B) BIBB.

2.2.1.3 Modbus/IP Router

Provide Modbus/IP Routers which perform layer 3 routing of MODBUS Protocol/ MODBUS TCP/IP packets over an IP network in accordance with MODBUS Protocol /MODBUS TCP/IP. The router must provide the appropriate connection to the IP network and connections to a non-IP MODBUS Protocol/MODBUS TCP/IP network. Modbus/IP Routers must support the Dynamic Host Configuration Protocol (DHCP; IETF RFC 4361) for IP configuration but must not rely on this service for configuration. Modbus/IP Routers must be capable of disabling the capability for remote configuration of Modbus routing information from the IP network.

2.2.2 Monitoring and Control (M&C) Controller Hardware

Provide Monitoring and Control (M&C) Controller Hardware which is a microprocessor-based direct digital control hardware and which communicates over the UMCS IP network using one of:

- a. CEA-709.1-D in accordance with CEA-852-C and using only Standard Network Variable Types (SNVTs) as defined by the LonMark SNVT List.
- b. ASHRAE 135 in accordance with ASHRAE 135 Annex J and using only Standard ASHRAE 135 services.

Monitoring and Control (M&C) Controller Hardware must either meet the requirements of the LonMark Interoperability Guide or be BTL Listed.

2.2.3 BACnet Supervisory Controller Hardware

Provide BACnet Supervisory Controller Hardware which is direct digital control hardware and which:

- a. is BTL Listed

- b. communicates using ASHRAE 135 over an IP network in accordance with ASHRAE 135 Annex J
- c. has a configurable Object_Name Property
- d. supports the following BIBBS
 - (1) DS-RP-B (Data Sharing-Read Property-B) BIBB for Objects requiring read access from the M&C Software
 - (2) DS-WP-B (Data Sharing-Write Property-B) BIBB for Objects requiring write access from the M&C Software.
 - (3) SCHED-E-B (Scheduling-External-B)
 - (4) AE-N-I-B (Alarm and Event-Notification Internal-B)
 - (5) AE-ACK-B (Alarm and Event-ACK-B)
 - (6) T-VMT-I-B (Trending-Viewing and Modifying Trends-Internal-B)
 - (7) T-ATR-B (Trending-Automated Trend Retrieval-B)
- e. has a Writable Recipient_List Property of the Notification Class Object

2.2.4 Control Protocol Gateways

Provide Control Protocol Gateways which perform bi-directional protocol translation between two of the following protocols, or between one of the following protocols and another protocol: CEA-709.1-D, ASHRAE 135, MODBUS Protocol, MODBUS TCP/IP, and OPC DA. Provide Control Protocol Gateways which also meet the following requirements.

- a. Gateways must have two or more separate network connections, each appropriate for the protocol and media used. A single network connection must not be used for both protocols.
- b. Gateways must be capable of being installed, configured and programmed through the use of instructions in the manual supplied by the Contractor.
- c. Provide and license to the Government all software required for gateway configuration.
- d. Gateways must retain their configuration after a power loss of an indefinite time, and must automatically return to their pre-power loss state once power is restored.
- e. Gateways must provide capacity for mapping all required points as indicated plus an additional 10 percent between the two protocols it uses.
- f. Gateways must, in addition, meet all requirements specified (in the following subparagraphs) for each of the two protocols it translates.

2.2.4.1 Gateway for CEA-709.1

For a gateways using CEA-709.1-D provide gateways which meet the following requirements in addition to the requirements for all gateways:

- a. It must allow bi-directional mapping of data in the Gateway to Standard Network Variable Types (SNVTs) according to the LonMark SNVT List.
- b. Gateways communicating CEA-709.1-D over an IP network must communicate in accordance with CEA-852-C.
- c. It must allow of its standard network variables (SNVTs) and support transmitting data using the "min, max, and delta" (throttling and heartbeat) methodology.
- d. It must provide the ability to label SNVTs.
- e. It must supply a LonMark external interface file (XIF) as defined in the LonMark XIF Guide for use with LNS tools and utilities.
- f. It must have a "service pin" which, when pressed, will cause the Gateway to broadcast its 48-bit NodeID and ProgramID over the network.
- g. It must provide a configurable self-documenting string.

2.2.4.2 Gateway for ASHRAE 135

For gateways using ASHRAE 135 provide gateways which meets the following requirements in addition to the requirements for all gateways:

- a. It must allow bi-directional mapping of data in the Gateway to Standard Objects as defined in ASHRAE 135.
- b. All ASHRAE 135 Objects must have a configurable Object_Name Property.
- c. It must be BTL Listed.
- d. Gateways communicating ASHRAE 135 over an IP network must communicate in accordance with ASHRAE 135 Annex J.
- e. Gateways communicating ASHRAE 135 to a field control systems must support the DS-RP-A (Data Sharing-Read Property-A) BIBB and the DS-WP-A (Data Sharing-Write Property-A) BIBB.
- f. Gateways communicating ASHRAE 135 to the M&C Software or to a BACnet Supervisory Controller must support the DS-RP-B (Data Sharing-Read Property-B) BIBB for Objects requiring read access from the M&C Software and the DS-WP-B (Data Sharing-Write Property-B) BIBB for Objects requiring write access from the M&C Software

2.2.4.3 Gateway for Modbus

For gateways that use MODBUS Protocol/MODBUS TCP/IP provide gateways that meet the requirements specified for all gateways and which allow bi-directional mapping of data in the Gateway to MODBUS Protocol/MODBUS TCP/IP registers using the four standard Modbus register types (Discrete Input, Coil, Input Register, and Holding Register). Gateways communicating MODBUS Protocol/MODBUS TCP/IP to the M&C Software must communicate via MODBUS Protocol/MODBUS TCP/IP over TCP/IP and must present floating point values, character values, and date values using the appropriate data type as specified in paragraph MODBUS REQUIREMENTS.

2.2.4.4 Gateway for OPC

For gateways that use OPC DA, provide gateways that meet the requirements specified for all gateways and which allow bi-directional mapping of data in the Gateway using OPC DA tags and which communicate over an IP network in accordance with OPC DA.

2.2.4.5 Gateway for DNP3

For gateways that use DNP3, provide gateways that meet the requirements specified for all gateways and which allow bi-directional mapping of data in the Gateway to DNP3 object groups and variations as defined by IEEE 1815. Gateways communicating DNP3 over an IP network must communicate in accordance with the LAN/WAN Networking volume of IEEE 1815.

2.3 COMPUTER HARDWARE

For computer hardware furnished under this specification provide standard products of a single manufacturer which advertises service in all 48 contiguous states, and provide only model currently in production. Except for PCI-E cards installed into expansion slots provided in a desktop or server computer in order to meet the requirements of this specification, do not modify computer hardware from the manufacturer configuration.

2.3.1 Server Hardware

Computer Server Hardware (server) will be furnished by the Government

2.3.2 Workstation Hardware (Desktop and Laptop)

The Government will provide the Computer Workstation Hardware (workstation) .

2.3.2.1 Processor

2.3.2.1.1 Desktop

Quad-core processor designed for desktop applications. Processor speed must be at least 75 percent of the speed of the fastest Intel desktop processor commercially available.

2.3.2.1.2 Laptop

Quad-core processor designed for laptop applications. Processor speed must be at least 50 percent of the speed of the fastest Intel laptop processor commercially available.

2.3.2.2 Random Access Memory (RAM)

300 percent of the recommended requirements of the software to be installed on the server and no less than 8GB.

2.3.2.3 Communications Ports

2.3.2.3.1 Desktop

Six USB ports.

2.3.2.3.2 Laptop

Two USB ports, plus a PCMCIA card slot or an additional USB port, plus an integral RS-232 serial port or an additional USB port and a USB to RS-232 serial adapter.

2.3.2.4 Hard Drive and Controller

2.3.2.4.1 Desktop

1.5TB or larger with a SATA-3 controller.

2.3.2.4.2 Laptop

250GB or larger solid state drive.

2.3.2.5 Optical Drive

DVD-RW drive

2.3.2.6 Video Output

2.3.2.6.1 Desktop

32-bit color with dual monitor support minimum resolutions of 1920 by 1080 at minimum refresh rates of 70 Hz and dual DVI or display port outputs.

2.3.2.6.2 Laptop

32-bit color with a minimum resolution of 1920 by 1080 at minimum refresh rates of 70 Hz and VGA or HDMI output.

2.3.2.7 Network Interface

2.3.2.7.1 Desktop

Integrated 1000Base-T Ethernet with RJ45 connector.

2.3.2.7.2 Laptop

Integrated 1000Base-T Ethernet with RJ45 connector and an integrated IEEE 802.11b/g/n wireless interface. The Laptop must have a physical switch for activation and deactivation of the wireless interface.

2.3.2.8 Monitor

2.3.2.8.1 Desktop

Dual widescreen flat panel LCD monitors sized as indicated but no less than 24 inch nominal with minimum resolutions of 1920 by 1080 pixels and a minimum refresh rate of 70Hz.

2.3.2.8.2 Laptop

LCD Screen sized as indicated but no less than 325 mm 13 inch nominal with a maximum supported resolution of no less than 1600 by 900 pixels.

2.3.2.9 Keyboard and Smart Card Reader

2.3.2.9.1 Desktop

101 key wired USB keyboard having a minimum 64 character standard ASCII character set based on ANSI INCITS 154 and an integral smart card reader compatible with a Department of Defense Common Access Card (CAC).

2.3.2.9.2 Laptop

Standard laptop keyboard. Internal smart card reader compatible with a Department of Defense Common Access Card (CAC).

2.3.2.10 Mouse

2.3.2.10.1 Desktop

2-button wired USB optical scroll mouse with a minimum resolution of 400 dots per inch.

2.3.2.10.2 Laptop

Integrated touch-pad plus a 2-button wired USB optical scroll mouse with a minimum resolution of 400 dots per inch.

2.3.3 Printers

Provide local or network printers as indicated. Provide local printers which have a USB interface. Provide network printers which have a 100Base-T or faster interface with an RJ45 connection and a firmware print spooler compatible with the Operating System print spooler.

2.3.3.1 Alarm Printer

Provide alarm printers which use sprocket-fed fanfold paper with adjustable sprockets for paper width up to 11 inches. Alarm printers must have programmable control of top-of-form. Provide floor stands with paper racks for alarm printers.

2.3.3.2 Laser Printer

Provide laser printers as indicated meeting the following minimum requirements:

Resolution	600 by 600 dots per inch
Printing Time	10 pages per minute
Data Buffer Size	16 Megabytes
Media Type	Paper and transparency film
Media Size	ANSI A(8.5 by 11 inches) and other sizes as indicated

Paper Cassette	250 sheet capacity
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2.4 COMPUTER SOFTWARE

2.4.1 Operating System (OS)

Provide the latest version of the DISAGold Master Windows Operating System. The Operating System media will be furnished by the Government. The Government will provide the Operating System license.

2.4.2 Office Automation Software

Office Automation Software will be furnished by the Government.

2.4.3 Virus Protection Software

Virus Protection Software will be furnished by the Government.

2.4.4 Disk Imaging (Backup) Software

Disk imaging (backup) software will be furnished by the Government.

2.4.5 M&C Controller Hardware Configuration Software

Provide M&C Controller Hardware Configuration Software consisting of the software required to configure, program, or configure and program each Monitoring and Control (M&C) Controller Hardware provided for the functions it performs.

2.4.6 BACnet Network Browser

Provide a BACnet Network Browser software that:

- a. Can perform full discovery of a ASHRAE 135 system including but not limited to discovery of all ASHRAE 135 devices, the ASHRAE 135 Objects and Properties of each device, and the standard ASHRAE 135 services supported by each device.
- b. Can read any ASHRAE 135 Property of any Object in any device. Proprietary Properties may be presented as read without further interpretation.
- c. Can write any Standard ASHRAE 135 Property of any Object in any device.
- d. Supports segmentation.
- e. Supports all of the following BIBBs:
 - (1) DM-ANM-A (Device Management-Automatic Network Management-A)
 - (2) DM-ADM-A (Device Management-Automatic Device Management-A)
 - (3) DM-DDB-A (Device Management-Dynamic Device Binding-A)
 - (4) DM-DOB-A (Device Management-Dynamic Object Binding-A)
 - (5) DS-RP-A (Data Sharing-Read Property-A)

(6) DS-RPM-A (Data Sharing-Read Property Multiple-A)

(7) DS-WP-A (Data Sharing-Write Property-A)

2.4.7 Monitoring and Control (M&C) Software

Provide monitoring and control (M&C) software which is a client-server software package with a graphical user interface (GUI) using web-browser based clients. Provide M&C Software which communicates viaASHRAE 135, and MODBUS Protocol/MODBUS TCP/IP, and OPC DA. The M&C Software may support other field control protocols. Provide M&C Software which is BACnet Testing Laboratories Certified ("Listed") as a B-AWS.

Provide a single software package which implements the Scheduling, Alarming, Trending, Graphical System Display, and System Display Editor functionality. Other specified M&C functionality may be implemented in the same software package or in additional software packages. As specified in PART 3 EXECUTION, the M&C Software must operate on Server hardware, except that software for Point Calculations and Demand Limiting may operate on M&C Controller Hardware.

2.4.7.1 M&C Software License

License the M&C Software as specified. Use of multiple copies of M&C Server software working in coordination and sharing data between them such that they function as, and appear to an operator as, a single M&C Server is permitted to meet these requirements.

2.4.7.1.1 Network Points

Provide M&C Software and licensing to support no less than than network points, and to be capable of expansion to support no less than 50,000 network points.

2.4.7.1.2 Web Clients

Provide M&C Software and licensing to support no less than 10 simultaneous web clients with no limit on the total number of web clients. M&C Software must be capable of expansion to support no less than 30 simultaneous web clients.

2.4.7.1.3 Calculations

Provide M&C Software and licensing to support no less than one calculated point for every ten network points (see "Network Points" above).

2.4.7.1.4 Other Points

For installations using M&C Software installed on M&C Controller Hardware (as opposed to Server hardware), provide additional licensing to support additional network points for the communications between portions of the M&C Software installed on different hardware. For example, if the Calculations requirement is performed by M&C Software installed on Controller hardware, the M&C Software must be licensed for additional network points to cover the network points required for communication between the Controller hardware and the Server hardware.

2.4.7.1.5 Alarming

Provide M&C Software and licensing to support alarm generation and the handling (routing) of alarms for no less than 10,000 points and ASHRAE 135 Alarm Event Notifications.

2.4.7.1.6 Trending

Provide M&C Software and licensing to support a minimum of 8,000 simultaneous trends.

2.4.7.1.7 Scheduling

Provide M&C Software and licensing to support a minimum of 200 user-definable schedules.

2.4.7.2 M&C Software Update Licensing

In addition to all other licensing requirements, provide M&C Software licensing which includes licensing of the following software updates for a period of no less than 5 years:

- a. Security and bug-fix patches issued by the M&C Software manufacturer.
- b. Security patches to address any vulnerability identified in the National Vulnerability Database at <http://nvd.nist.gov> with a Common Vulnerability Scoring System (CVSS) severity rating of MEDIUM or higher.

2.4.7.3 Supported Field Control Protocols

Provide M&C Software which supports field control protocols as follows:

- b. The M&C Software must include a driver to ASHRAE 135 over IP in accordance with ASHRAE 135 Annex J.
- c. The M&C Software must include a driver to MODBUS Protocol/MODBUS TCP/IP over TCP/IP. The M&C Software must be capable of reading and writing the Modbus data types as defined in paragraph MODBUS REQUIREMENTS and must, in addition, be capable of manipulating and presenting arbitrary data formats derived from the four standard Modbus data types.
- d. The M&C Software must be an OPC DA client.
- f. The M&C Software may, in addition, include drivers to other protocols.

Provide M&C Software capable of reading values from and writing values to points via any supported field protocol, and capable of reading values from one field protocol and writing them to another. All points obtained from any field protocol must be available to all M&C Software functionality.

2.4.7.4 Supported Enterprise Protocols

Provide M&C Software which supports oBIX, BACnet Web Services or OPC as an enterprise protocol and which meets the following requirements:

- a. It is able to read values from any point or collection of points (network point, internal point, trend log or schedule) and transmit

these values via the enterprise protocol.

- b. It is able to receive data via the enterprise protocol and use this data to change the value of any point.
- c. License the enterprise protocol interface to the project site and document the interface such that any system capable of communicating with that protocol can be used to read and write data from the M&C Software.

2.4.7.5 Point Information

Every point, both network and internal, in the M&C Software must contain the following fields:

2.4.7.5.1 Name

A configurable name used for identification of the point within the M&C Software.

2.4.7.5.2 Description

A configurable description of no less than 80 alpha-numeric characters.

2.4.7.5.3 Value

A field containing the current point value.

2.4.7.5.4 Units

A field containing the engineering units.

2.4.7.5.5 Source

A field identifying the source of the point. For network points, this is generally the address or identification of the field device (for example, the Domain-Subnet-Node address for LonWorks field control devices or the DeviceID for BACnet devices).

2.4.7.6 Point Calculations

Provide M&C software capable of performing calculations and computing the value of a calculated point based on the values of two or more network points and calculated points. Mathematical operators must include: addition, subtraction, multiplication, division, exponentiation (y^x , power), square root, reciprocal, natural logarithm, sin, cos, tan, arcsin, arccos, arctan, and parenthesis. Pi and e must be available as constants for use in calculations.

2.4.7.7 Browser-Based Graphical User Interface (GUI)

Provide M&C Software which includes a web-browser based (client-server) graphical user interface through which all M&C Software functionality, except for the Graphics Editor, System Display Editor, report configuration, point calculation configuration, and enterprise protocol configuration, is accessible.

Provide graphical user interface web server and web clients meeting the following requirements:

- a. The web server must use HTTPS based on the Transport Layer Security (TLS) Protocol in accordance with IETF RFC 7465 using a Government-furnished certificate.
- b. The graphical user interface must be Common Access Card (CAC) enabled: It must support web client authentication using certificates obtained from a Department of Defense Common Access Card (CAC) Smart Card.
- c. The web client must operate on any version of Windows currently supported by Microsoft.
- d. The web client must function in the most recent three version of Internet Explorer and the most recent three versions of Firefox.
- e. The web client must not require a connection to any server other than the M&C Server.
- f. The web client must function in a browser with Java, Shockwave, Silverlight, and Flash installed. The client may require a download of mobile code from the M&C Server, but must not require the download of additional browser plug-ins or add-ins and there must be no limit on the number of downloads. The client must not require ActiveX.

2.4.7.8 Passwords

Provide M&C software with user-based access control to M&C functionality. The M&C Software must recognize at least 100 separate users and have at least 4 levels of user permissions. User permission levels (from most restrictive to most permissive) must include:

- a. Permission Level 1: View-only access to the graphical user interface.
- b. Permission Level 2: Permission Level 1 plus acknowledge alarms and set up (configure) trends and reports.
- c. Permission Level 3: Permission Level 2 plus override points and set up (configure) alarms, schedules and demand limiting.
- d. Permission Level 4: Permission Level 3 plus create and modify Graphical System Displays using the System Display Editor.

Passwords must not be displayed and must not be logged. The system must maintain a disk file on the server hardware logging all activity of the system. This file must maintain, as a minimum, a record of all operators logged onto the system, alarm acknowledgments, commands issued and all database modifications. If the file format is not plain ASCII text, provide a means to export or convert the file to plain ASCII text. Provide a mechanism for archiving the log files for long term record storage.

2.4.7.9 Graphical System Displays

Provide graphical displays consisting of building system (air handler units, VAV boxes, chillers, cooling towers, boilers, etc.) graphic displays. Data associated with an active display must be updated at least once every 5 seconds.

2.4.7.9.1 Navigation Scheme

System graphic displays of building systems and points must be hierarchical displays using a building-to-equipment point-and-click navigation scheme which allows navigation from a garrison-wide display, through a building-wide display to the individual units. Each display must show the building name and number. Each display must show system wide data such as outside air temperature and humidity in the case of an HVAC system application.

- a. For each Building or Building Sub-Area display, show the building foot print and basic floor plan, and clearly show and distinguish between the individual zones and the equipment serving each zone and space. Show all space sensor and status readings, as applicable, for the individual zones such as space temperature, humidity, occupancy status, etc. Show the locations of individual pieces of monitored and controlled equipment.
- b. For each equipment display show a one-line diagram control schematic representation of the individual pieces of equipment using the symbols and M&C point data types as specified. Use different colors and textures to indicate various components and real time data. Use consistent color and texture meanings across all displays.
- c. Provide displays which clearly distinguish between the following point data types and information:
 - (1) Real-time data.
 - (2) Other user-entered data.
 - (3) Devices in alarm (unacknowledged).
 - (4) Out-of-range, bad, or missing data.
 - (5) Points which are overridden.

2.4.7.9.2 Navigation Commands

Provide system displays which support English language operator commands via point-and-click mouse or keyboard entry for defining and selecting points, parameters, graphics, report generation, and all other functions associated with operation. The operator commands must be usable from any operator workstation with individual operator passwords as specified.

2.4.7.10 Graphic Editor

Provide a fully featured graphics editor and capable of creating custom graphics and graphic symbols for use by the System Display Editor.

2.4.7.11 System Display Editor

Provide a system display editor which allows the user to create, modify, and delete graphic displays. The display editor may have a separate user interface and is not required to be accessible via the web browser interface. Provide a display editor which includes the following functions:

- a. Create and save displays. Save an existing or modified display as a

new display (i.e. "save as")

- b. Group and ungroup graphics, where graphics include both alphanumeric and graphic symbols, and where a grouped graphic is manipulated as a single graphic.
- c. Place, locate, resize, move, remove, reposition, rotate and mirror a graphic on a display.
- d. Overlay graphics over other graphics and assign depths such that when there are coincident graphics the one on top is visible.
- e. Modify graphic properties based on the value of network points and create conditions governing the display of a graphics such that different graphics are visible based on the value of network points or calculated points
- f. Integrate real-time data with the display.
- g. Establish connecting lines.
- h. Establish sources of latest data and location of readouts.
- i. Display analog values as specified.
- j. Assign conditions which automatically initiate a system display.
- k. Include library of display symbols which include: Pump, Motor, Two- and Three-way Valves, Flow Sensing Element, Point and Averaging Temperature Sensors, Pressure Sensor, Humidity Sensor, Single and Double Deck Air Handling Unit, Fan, Chiller, Boiler, Air Compressor, Chilled Water Piping, Steam Piping, Hot Water Piping, Ductwork, Unit Heater, Pressure Reducing Valve, Damper, Electric Meter, Limit Switch, Flow Switch, High- and Low- Point and Averaging Temperature Switches, High- and Low- Pressure Switches, Coil, Solenoid Valve, Filter, Condensing Unit, Cooling Tower, Variable Frequency Drive (VFD), Heat Exchanger, Current Sensing Relays, Generator, Circuit Breaker, Transformer, Tank. Symbols must at a minimum conform to ASHRAE FUN IP where applicable.

2.4.7.12 Scheduling

- a. Provide M&C software capable of changing the value of any network point according to a schedule. The M&C Software must be capable of scheduling points to any value, including a "null" or invalid value if one is defined for the data type of the point.
- b. The specified scheduling functions must be operator accessible and adjustable via the graphical user interface. Each schedule must be able to change the value of multiple points. The M&C software must reinforce all schedules by transmitting the scheduled value no less than once every 30 minutes.
- c. The M&C software must be capable of performing time synchronization and configuring Schedule Objects in ASHRAE 135 field devices in accordance with the DM-MTS-A (Device Management-Manual Time Synchronization-A).

- e. The M&C Software must include a scheduling graphic display, accessible via the graphical user interface, with the following fields and functions:
 - (1) Current date and time.
 - (2) System identifier(s) and name(s), including location information such as Building name(s) and number(s).
 - (3) System group. Systems grouped by the user to perform according to a common schedule.
 - (4) Weekly schedules. For each system, a weekly schedule based on a seven day per week schedule with independent schedules for each day of the week including no less than 6 value changes per day.
 - (5) Holiday and special event schedules. Support for holiday and special event calendar schedules independent of the daily schedule. Special event schedules include one-time events and recurring events. Scheduling of one-time events include the beginning and ending dates and times of the event. Holiday and special event schedules must have precedence over device weekly schedules.

2.4.7.13 Alarms

Provide M&C Software meeting the following minimum requirements for alarms:

- a. The M&C software must be capable of generating alarms by comparing the value of any point from any connected system to user-configurable limits, and configuring alarms in ASHRAE 135 field devices in accordance with the B-AWS BIBBs
- b. The M&C software must be capable of handling (routing) alarms generated by the M&C Software, and alarms received as an ASHRAE 135 Alarm Event Notifications.
- d. The M&C software must support at least two alarm priority levels: critical and informational. Critical alarms must remain in alarm until acknowledged by an operator and the alarm condition no longer exists; informational alarms must remain in alarm until the alarm condition no longer exists or until the alarm is acknowledged.
- e. The creation, modification, and handling (routing) of alarms must be fully accessible and fully adjustable from the graphical user interface.
- f. Alarm Data. Alarm data to be displayed and stored must include:
 - (1) Identification of alarm including building, system (or sub-system), and device name.
 - (2) Date and time to the nearest second of occurrence.
 - (3) Alarm type:
 - (a) Unreliable: Indicates that the source device has failed due to the sensing device or alarm parameter being out-of-range or bad data.

- (b) High Alarm.
 - (c) Low Alarm.
 - (4) Current value or status of the alarm point, including engineering units
 - (5) Alarm limits, including engineering units.
 - (6) Alarm priority.
 - (7) Alarm Message: A unique message with a field of at least 60 characters. Assignment of messages to an alarm must be an operator editable function.
 - (8) Acknowledgement status of the alarm including the time, date and user of acknowledgement.
- g. Alarm Notification and Routing: The M&C software must be capable of performing alarm notification and routing functions. Upon receipt of ASHRAE 135 event notification, OPC alarm, or upon generation of an alarm the M&C software must immediately perform alarm notification and routing according to an assigned routing for that alarm. The M&C software must support at least 100 alarm routes, where an alarm route is a unique combination of any of the following activities:
- (1) Generate a pop-up up active clients. The pop-up display must include the Alarm Data. Alarms must be capable of being acknowledged from the pop-up display by operators with sufficient permissions. Pop-up must be displayed until acknowledged.
 - (2) Send an e-mail message via simple mail transfer protocol (SMTP; RFC 821). The e-mail must contain a configurable message and all alarm data. The e-mail recipient and scripted message must be user configurable for each alarm route.
 - (3) Print alarms to designated alarm printers. The printed message must be the same as the pop-up message.
- h. Alarm Display and Acknowledgement. The M&C software must include an alarm display. Alarms must be available for display at each workstation as shown, along with all associated alarm data. Alarms must be capable of being acknowledged from this display. Multiple alarms must be capable of being acknowledged using a single command. Operator acknowledgment of one alarm must not automatically be considered as acknowledgment of any other alarm nor may it inhibit reporting of subsequent alarms.
- i. Alarm Storage and Reports: The M&C software must store each alarm and its associated alarm data to hard disk and retain this information after the alarm no longer exists. The stored data must be sortable, searchable, and printable.
- 2.4.7.14 Trending
Provide M&C software capable of creating, modifying, uploading and archiving ASHRAE 135 Trend Objects in field devices in accordance with the B-AWS BIBBs and of performing real-time trending with a minimum trending rate of 100 points per second .

- a. The M&C Software must include a graphical display for trend configuration, creation and deletion accessible through the graphical user interface. Each trend must be user-configurable for:
 - (1) Point to trend.
 - (2) Sampling interval: adjustable between 1 second and 1 hour.
 - (3) Start and Stop Time of Trend: Start and stop times determined by one or more of the following methods:
 - (a) Start time and stop time
 - (b) Start time and duration
 - (c) Start time and number of samples
- b. The M&C software must be capable of displaying and printing a graphical representation of each trend, and of multiple trended points on the same graph. The software must be capable of saving trend logs to a file. If the file format is not plain ASCII text in a Comma-Separated-Value (CSV) format, provide a means to export or convert the file to plain ASCII text in a CSV format.

2.4.7.15 Electrical Power Demand Limiting

Provide M&C software which includes demand limiting functionality capable of performing electrical demand limiting such that it can change the occupancy mode or setpoint of field control system hardware via a network point based on a projected demand in order to maintain demand below a configured target. The demand target must incorporate real-time pricing data. The demand limiting algorithm must incorporate priority levels such that low priority equipment is adjusted before high-priority equipment. The demand limiting algorithm must generate a critical alarm when it begins to impact the system and a critical alarm if the demand target is exceeded.

2.4.7.16 Report Generation

Provide M&C Software capable of generating, saving and printing reports. Dynamic operation of the system must not be interrupted to generate a report. The report must contain the time and date when the samples were taken, and the time and date when the report was generated. The software must be capable of saving reports to a PDF file and to a file compatible with the provided Office Automation Software.

The software must allow for automatic and manual generation of reports. For automatic reports an operator must be able to specify the time the initial report is to be generated, the time interval between reports, end of period, and the output format for the report. Manual report generation must allow for the operator to request at any time the output of any report.

2.4.7.17 Custom Report Generation

Provide M&C software capable of generating custom reports, including but not limited to the following standard reports:

2.4.7.17.1 Electrical Power Usage Report

An electrical power Usage summary, operator selectable for substations, meters, or transducers, individual meters and transducers, any group of meters and transducers, and all meters for an operator selected time period. The report must include the voltage, current, power factor, electrical demand, electrical power consumption, reactive power (Kvar) for each substation, facility, system or equipment as selected by the operator. The report must be automatically printed at the end of each summary period and include:

- a. Total period consumption.
- b. Demand interval peak for the period, with time of occurrence.
- c. Energy consumption (kWh) over each demand interval.
- d. Time-of-use peak, semi-peak, off-peak, or baseline total kWh consumption.
- e. Reactive power during each demand interval.
- f. Power factor during each demand interval.
- g. Outside air (OA) temperature and relative humidity (RH) taken at the maximum and minimum of OA temperature of the report period with the time and dates of occurrence. At the installation's peak demand interval, the OA temperature and RH must also be recorded.
- h. Calculated heating and cooling degree days based on a 65 degrees F balance point.

2.4.7.17.2 Electrical Peak Demand Prediction Report

A report based on the demand limiting program, which includes:

- a. Electrical Demand Target (EDT).
- b. Actual peak and predicted peak for each demand interval for that day.
- c. Predicted demand for the next demand interval.

2.4.7.17.3 Energy usage Report

An energy usage summary, operator selectable, for a unit, building, area, installation, and the entire UMCS. The report must be divided by utility, and must be capable of reporting on at least four separate utilities. The report must include the following information:

- a. Beginning and ending dates and times.
- b. Total energy usage for each utility for the current and previous day.
- c. Total energy usage for each utility for the current and previous month.
- d. Maximum 15-minute interval average rate of consumption for each utility for the current and previous day and current and previous month.

- e. Outside air (OA) temperature and OA humidity for current and previous month and current and previous day:
 - (1) Average temperature and humidity.
 - (2) Temperature and humidity at maximum and minimum OA temperature with time and date of occurrence.
 - (3) Temperature and humidity at maximum and minimum humidity with time and date of occurrence.
 - (4) Temperature and humidity at the installation's peak demand interval with the time and date of occurrence
- f. Calculated degree days. Reports which include humidity must be configurable to report either dewpoint or relative humidity.

2.4.7.17.4 Water Usage Report

A water usage summary, operator selectable, for a unit, building, area, installation, and the entire UMCS. The report must include the following information:

- a. Beginning and ending dates and times.
- b. Total energy water usage for the current and previous day.
- c. Total water usage for the current and previous month.

2.4.7.17.5 Alarm Report

Outstanding alarms by building or unit, including time of occurrence.

2.4.7.17.6 M&C Software Override Report

Points overridden by the M&C Software, including time overridden, and identification of operator overriding the point.

2.4.7.17.7 Run Time Reports

A report totalizing the accumulated run time of individual pieces of equipment. The operator must be able to define equipment groupings and to generate reports based on these groupings.

2.4.7.17.8 Cooling Tower Profiles

A cooling tower profile for each cooling tower as indicated, including:

- a. Total daily and monthly on-time (each fan).
- b. Number of on and off transitions (each fan).
- c. Maximum and minimum daily condenser water temperature and the time of occurrence for the current and previous months.
- d. Total daily and monthly makeup water consumption.

2.4.7.17.9 Chiller usage Report

A report of the operation of each chiller as shown on a daily and monthly basis, for each of at least 10 discrete loading levels. The report must include:

- a. Average power for the month at each level in kW
- b. Total monthly energy use in kWh at each level
- c. Total monthly energy use in kWh for the chiller (all levels)
- d. Total daily run hours at each level
- e. Total Monthly run hours at each level

2.4.7.17.10 Device Offline Report

A report listing all offline devices in all ASHRAE 135 building control systems integrated to the M&C Software.

2.5 UNINTERRUPTIBLE POWER SUPPLY (UPS)

Provide uninterruptible power supplies (UPS) as self contained devices suitable for installation and operation at the location of Server and Workstation hardware and sized to provide a minimum of 20 minutes of operation of the connected hardware. Equipment connected to the UPS must not be affected in any manner by a power outage of a duration less than the rated capacity of the UPS. Provide the UPS complete with all necessary power supplies, transformers, batteries, and accessories. Provide UPS which include visual indication of normal power operation, UPS operation, abnormal operation and visual and audible indication of AC input loss and low battery power. Provide UL 1778 approved UPS. UPS powering Server Hardware must notify the server via USB interface of impending battery failure.

2.6 RACKS AND ENCLOSURES

2.6.1 Enclosures

Enclosures supplied as an integral (pre-packaged) part of another product are acceptable. Provide two Enclosure Keys for each lockable enclosure on a single ring per enclosure with a tag identifying the enclosure the keys operate. Provide enclosures meeting the following minimum requirements:

2.6.1.1 Outdoors

For enclosures located outdoors, provide enclosures meeting NEMA 250 Type 3 requirements.

2.6.1.2 Mechanical and Electrical Rooms

For enclosures located in mechanical or electrical rooms, provide enclosures meeting NEMA 250 Type 2 requirements.

2.6.1.3 Other Locations

For enclosures in other locations including but not limited to occupied spaces, above ceilings, and in plenum returns, provide enclosures meeting

NEMA 250 Type 1 requirements.

2.6.2 Equipment Racks

Provide standard 19 inch equipment racks compatible with the electronic equipment provided. Racks must be either aluminum or steel with bolted or welded construction. Steel equipment racks must be painted with a flame-retardant paint. Guard rails must be included with each equipment rack and have a copper grounding bar installed and grounded to the earth.

PART 3 EXECUTION

3.1 EXISTING CONDITIONS SURVEY

Perform a field survey, including but not limited to testing and inspection of equipment to be part of the UMCS, and submit an Existing Conditions Report documenting the current status and its impact on the Contractor's ability to meet this specification. For field control systems to be integrated to the UMCS which are not already connected to the UMCS IP network, verify the availability of the building network backbone at the FPOC location, and verify that FPOCs shown as existing are installed at the FPOC location.

3.2 DRAWINGS AND CALCULATIONS

3.2.1 UMCS IP Network Bandwidth Usage Estimate

Provide a UMCS IP Network Bandwidth Usage Estimate for a small, medium or large systems. In this estimate account for field control systems using all M&C required protocols and the integration of field control system via gateways. Define all assumptions used to create the estimate, including but not limited to: trending, fast trends for commissioning, schedules, alarms, display of system graphics and load shedding.

3.2.2 UMCS Contractor Design Drawings

Revise and update the Contract Drawings to include details of the system design and all hardware components, including contractor provided and Government furnished components. Details to be shown on the Design Drawing include:

- a. The logical structure of the network, including but not limited to the location of all Control Hardware (including but not limited to each BACnet Supervisory Controller, Control Protocol Gateway, Control Protocol Router, and Monitoring and Control (M&C) Controller).
- b. Manufacturer and model number for each piece of Computer Hardware and Control Hardware.
- c. Physical location for each piece of Computer Hardware and Control Hardware.
- d. Version and service pack number for all software and for all Control Hardware firmware.

3.2.3 As-Built Drawings

Prepare draft as-built drawings consisting of Points Schedule drawings for the entire UMCS, including Points Schedules for each Gateway, and an

updated Design Drawing including details of the actual installed system as it is at the conclusion of Start-Up and Start-Up Testing. Provide As-Built Drawings which include details of all hardware components, including contractor provided and Government furnished components. In addition to the details shown in the design drawings, the as-built drawing must include:

- a. IP address(es) and Ethernet MAC address(es) as applicable for each piece of Control Hardware (including but not limited to each BACnet Supervisory Controller, Control Protocol Gateway, Control Protocol Router, and Monitoring and Control (M&C) Controller).
- b. IP address and Ethernet MAC address for each computer server, workstation, and networked printer.
- c. Network identifier (name) for each printer, computer server and computer workstation.
- d. List of ports, protocols and network services for each device connected to an IP network.
- e. Network Addresses: ASHRAE 135 address and Object_ID of the Device Object for all Control Hardware using ASHRAE 135. MODBUS Protocol/ MODBUS TCP/IP address for all Control Hardware using MODBUS Protocol/ MODBUS TCP/IP.

Prepare Draft As-Built Drawings upon the completion of Start-Up and Start-Up Testing and Final As-Built Drawings upon completion of PVT Phase II.

3.3 INSTALLATION REQUIREMENTS

3.3.1 General

Install system components as shown and specified and in accordance with the manufacturer's instructions and provide necessary interconnections, services, and adjustments required for a complete and operable system. Install communication equipment and cable grounding as necessary to preclude ground loops, noise, and surges from adversely affecting system operation. Install Fiber Optic cables and wiring in exposed areas, including low voltage wiring but not including network cable in telecommunication closets, in metallic raceways or EMT conduit as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Do not install equipment in any space which experiences temperatures or humidity outside of the rated operating range of the equipment.

3.3.2 Isolation, Building Penetrations and Equipment Clearance

Provide dielectric isolation where dissimilar metals are used for connection and support. Make all penetrations through and mounting holes in the building exteriors watertight. Drill or core drill holes in concrete, brick, steel and wood walls with proper equipment. Seal conduits installed through openings with materials which are compatible with existing materials. Seal openings with materials which meet the requirements of NFPA 70 and SECTION 07 84 00 FIRESTOPPING.

3.3.3 Nameplates

Provide Nameplates for all Control Hardware and all Computer Hardware.

Attach Nameplates to the device in a conspicuous location.

3.4 INSTALLATION OF EQUIPMENT

3.4.1 Wire and Cable Installation

Install system components and appurtenances in accordance with NFPA 70, manufacturer's instructions and as indicated. Provide necessary interconnections, services, and adjustments required for a complete and operable signal distribution system. Label components in accordance with TIA-606. Firestop Penetrations in fire-rated construction in accordance with Section 07 84 00 FIRESTOPPING. Install conduits, outlets and raceways in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Install wiring in accordance with TIA-568.1 and as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Mark wiring terminal blocks and outlets in accordance with TIA-606. Do not install non-fiber-optic cables in the same cable tray, utility pole compartment, or floor trench compartment with power cables. Properly secure and install neat in appearance cables not installed in conduit or raceways.

3.4.2 Grounding

Install signal distribution system ground in accordance with TIA-607 and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Connect equipment racks to the electrical safety ground.

3.4.3 Power-Line Surge Protection

Protect equipment connected to ac circuits must be protected against or withstand power-line surges. Provide equipment protection which meets the requirements of IEEE C62.41. Do not use fuses for surge protection.

3.4.4 IP Addresses

For all Control Hardware requiring an IP address on the UMCS IP Network, coordinate with the base to obtain IP addresses .

3.4.5 Computer Hardware and Software

3.4.5.1 Hardware Installation

Install Computer Hardware as specified and indicated. Power Computer Servers through a UPS, and install and configure them such that the server automatically undergoes a clean shutdown upon low battery signal from the UPS.

3.4.5.2 Software Installation

Install software as follows:

- c. BACnet Network Browser: Install the BACnet Network Browser software as indicated. Install the BACnet Network Browser on workstation hardware.
- e. Monitoring and Control Software: Install the monitoring and control (M&C)software as shown. Except for M&C Software performing Point Calculations or Electrical Peak Demand Limiting, install M&C Software on server hardware. Install M&C Software performing Point

Calculations or Electrical Peak Demand Limiting on either server hardware or Monitoring and Control (M&C) Controller Hardware. Install M&C Software in a manner consistent with its B-AWS listing such that it provides all functionality of a B-AWS.

Provide sufficient computer hardware and M&C Controller Hardware and install M&C Software to support the number of points required in PART 2 (PRODUCTS), regardless of the number of points integrated under this project specification. Note that meeting this requirement may entail the installation of unused hardware or spare point licenses to accommodate the full number of required points in order to allow for integration of future field control systems.

- f. M&C Controller Hardware Configuration Software: Install the M&C Controller Hardware Configuration Software on server hardware.
- g. Operating system: Install the OS on each Server and Workstation and configure user names and passwords. Coordinate with for user names and passwords.

Where software requires connection to an IP device outside of the UMCS, coordinate with base to obtain access to a Government-furnished server to provide the needed functionality. Do not connect to any device outside of the UMCS without explicit permission from base.

3.4.5.3 Monitoring and Control (M&C) Software Configuration

Configure the Monitoring and Control (M&C) Software as specified, as indicated and as follows:

- a. Set up M&C Software user accounts. Coordinate user accounts and permissions with the Controls shop supervisor.
- b. Change the default password on all accounts. Remove or disable any accounts which do not require authentication (such as guest accounts).
- c. Configure e-mail capability to use the government furnished SMTP server using the following server information.
- d. Disable all ports, protocols, and network services other than those required or specifically permitted by this Section. Services to be disabled include but are not limited to: FTP, Telnet and SSH.
- e. Install web server certificate. Obtain certificate from .

3.4.5.4 Control Hardware Installation

Install Control Hardware in a lockable enclosure and as specified. Configure Control Hardware as specified, as required to meet the functions for which the hardware is used and as follows:

- a. Disable all ports, protocols, and network services other than those required or specifically permitted by this Section. Services to be disabled include but are not limited to: FTP, Telnet, SSH, and HTTP. When disabling of ports, protocols and services is not supported by a product, obtain an exception from this requirement prior to using the product and document non-compliance on the Product Data Sheets and

As-Built drawings.

- b. Change the default passwords in all Control Hardware which have passwords. Coordinate new passwords with the Controls shop supervisor.

3.5 INTEGRATION OF FIELD CONTROL SYSTEMS

Fully integrate the field control systems in accordance with the following three step sequence and as specified and shown.

STEP 1: Install and configure Control Hardware as necessary to connect the field control system to the FPOC, which is part of the UMCS IP network, and to provide control protocol translation and supervisory functionality.

STEP 2: Add Field Control System to M&C Software: Perform system discovery, system database merges, or any other actions necessary to allow M&C Software access to the field control system.

STEP 3: Configure M&C Software to provide monitoring and control of the field control system, including but not limited to the creation of system displays and the configuration of scheduling, alarming, and trending.

3.5.1 Integration Step 1: Install Control Hardware

Install Control Hardware as specified at the FPOC location to connect the field control system to the UMCS IP network via the FPOC and, if necessary, to provide control protocol translation and supervisory functionality. Coordinate all connections and other activities related to an FPOC with base. Depending on the field control system media and protocol this must be accomplished through one of the following:

- a. Connect the existing field control network hardware at the FPOC location to the FPOC.
- b. Install a Control Protocol Gateway connected to both the field control network and the FPOC.
- c. Install a Control Protocol Router connected to both the field control network and the FPOC.
- d. Install a Control Protocol Gateway connected to the field control network. Then install a Control Protocol Router connected to both the Control Protocol Gateway and the FPOC.

In addition, for integration of field control systems via ASHRAE 135, also install a BACnet Supervisory Controller as needed to implement scheduling, alarming and trending in the field control system. The BACnet supervisory controller may be the same device as the control protocol gateway or router.

3.5.1.1 Installation of Control Protocol Gateway

If the field control system uses a protocol which is not supported by the M&C Software, install a gateway to convert the field control system protocol to ASHRAE 135, or to MODBUS Protocol/MODBUS TCP/IP, or to OPC DA. Install additional field control system network media and hardware as needed to connect the Gateway to the field control system. Connect the Gateway according to one of the two following methods:

- a. Connect the Gateway to the field control network and to the FPOC. .
- b. Connect the Gateway to the field control network and to a BACnet/IP Router, or to a Modbus/IP Router installed as specified.

Create and configure points and establish network communication between the Control Protocol Gateway and the field control system to provide points from the field control system to the M&C software.

3.5.1.2 Installation of Control Protocol Router

If there is not an existing connection between the FPOC and the field control network, install a BACnet/IP Router, or a Modbus/IP Router to connect the field control network to the FPOC. Install additional field control system network media as needed to connect the Router to the field control system.

3.5.1.3 Installation of BACnet Supervisory Controller

If required for implementation of scheduling, alarming and trending, install a BACnet Supervisory Controller connected to the building control system IP network and configure it to provide scheduling, alarming and trending functions for the field control system. When the BACnet Supervisory Controller is the same device as a control protocol router or gateway, install it in accordance with the installation requirements for a router or gateway.

3.5.2 Integration Step 2: Add Field Control System to M&C Software

Perform system discovery, system database merges, or any other actions necessary to allow M&C Software access to points and data in the field control system.

3.5.2.1 Integration of Field Control Systems Via ASHRAE 135

Use the M&C Software to fully discover the field control system. Full discovery of a field control system includes but is not limited to discovery of all ASHRAE 135 devices, all standard ASHRAE 135 Objects and Properties of each device, and all standard ASHRAE 135 services supported by each device.

3.5.2.2 Integration of Field Control Systems Via Modbus

Survey the field control system to create Points Schedules. Using these Points Schedules make all points from the field control system available in the M&C Software.

3.5.2.3 Integration of Field Control Systems Via OPC DA

Establish a connection between the M&C Software OPC DA client and the field control system OPC DA server and make all points from the field control system available in the M&C Software.

3.5.2.4 [Enter Appropriate Subpart Title Here]Integration of Field Control Systems Via Other (non-ASHRAE 135, non-Modbus, non-OPC DA) Protocols

Perform all actions necessary to make all points from the field control system available in the M&C Software.

3.5.3 Integration Step 3: Configure M&C Software

Configure M&C Software to provide monitoring and control of the field control system, including but not limited to the creation of system displays and the configuration of scheduling, alarming, and trending.

3.5.3.1 Configure M&C Software Communication

Create and configure points and establish network communication between M&C Software and Field Control Systems as specified to support M&C Software functionality:

- a. Update points on currently active displays via polling as necessary to meet M&C Software display refresh requirements.
- b. Send points used for overrides to the device receiving the override as shown on the Points Schedule. For BACnet systems write operator overrides with a priority of 8 and demand limiting overrides with a priority of 10.
- c. For Notification Class Objects used for Alarms, configure the Recipient_List Property to point to the appropriate M&C Software process. Use the ConfirmedEventNotification service for events from ASHRAE 135 field control systems used for alarms. Poll points from MODBUS Protocol/MODBUS TCP/IP field control systems used for alarms at 5 minute intervals. For points from OPC DA field control systems used for alarms use a subscription or poll the point at 5 minute intervals.
- d. Update points used for currently active trends via polling as necessary to meet trend interval requirements.
- e. Send points used for scheduling to the field control system with a maximum time between subsequent transmissions of the point of 30 minutes. .

Edit the Description field of each point to include the Real Property Unique IDs (RPUID) associated with that point as shown on the Points Schedule

3.5.3.2 Configure M&C Software Functionality

Fully configure M&C Software functionality using the M&C Software capabilities specified in PART 2 of this Section.

- a. Create System Displays using the project site sample displays, including overrides, as shown on the Points Schedule and as specified. Label all points on displays with full English language descriptions. Configure user permissions for access to and executions of action using graphic pages. Coordinate user permissions with the Controls shop supervisor
- b. Configure alarm generation and alarm handling as shown on the Points Schedule, as shown on the Alarm Routing Schedule, and as specified. Create and configure Objects in BACnet Supervisory Controllers and in the field control system to support alarming as shown on the Points Schedule and as specified. Alarm events with priority 112 are critical and events with priority 224 are non-critical. For alarm

events with other priorities, treat events with priorities of 200 or above as non-critical, and all others as critical. For alarms requiring notification via text message or e-mail, configure the alarm notification to use the specified Government furnished SMTP server to send the alarm notification.

- c. Configure scheduling as indicated and as shown on the points schedule. Configure M&C Software scheduling functionality to schedule Modbus systems and OPC systems. Create and configure Schedule Objects in BACnet Supervisory Controllers or in the field control system.

Create and configure displays for configuration of M&C Software schedules and Schedule Objects in the field control system. Label schedules and scheduled points with full English-language descriptors. Provide a separate configuration capability for each schedule. A single configuration display may be used to configured multiple schedules, provided that each schedule is separately configurable from the display.

- d. Create M&C Software trends for required points as shown on the Points Schedule and as specified. Create and configure Trend Objects in BACnet Supervisory Controllers and in the field control system as shown on the Points Schedule and as specified. Trend points at 15 minute intervals.

Create and configure displays for creation and configuration of trends and for display of all trended points.

- e. Configure Demand Limiting as shown on the Demand Limit Schedule and Points Schedule and as specified.
- f. Configure M&C Software standard reports.

3.6 START-UP AND START-UP TESTING

Test all equipment and perform all other tests necessary to ensure the system is installed and functioning as specified. Prepare a Start-Up and Start-Up Testing Report documenting all tests performed and their results and certifying that the system meets the requirements specified in the contract documents.

3.7 PERFORMANCE VERIFICATION TEST (PVT)

3.7.1 PVT Phase I Procedures

Provide PVT Procedures which include:.

- a. Network bandwidth usage and available bandwidth (throughput) measurements. Network bandwidth usage must reference the normal usage network Bandwidth Calculations.
- b. Test System Reaction during PVT: The total system response time from initiation of a control action command from the workstation, to display of the resulting status change on the workstation must not exceed 20 seconds under system normal heavy load conditions assuming a zero response time for operation of the node's control device.
- c. Verification of IP Connectivity.

d. Verification of configuration of M&C Software functionality.

3.7.2 PVT Phase I

Demonstrate compliance of the control system with the contract documents. Using test plans and procedures previously approved by the Government, demonstrate all physical and functional requirements of the project. Upon completion of PVT Phase I and as specified, prepare and submit the PVT Phase I Report documenting all tests performed during the PVT and their results. In the PVT report, include all tests in the PVT Procedures and any other testing performed during the PVT. Document failures and repairs with test results.

3.7.3 PVT Phase II

Include Basic Training as part of PVT Phase II. Failures or deficiencies of the UMCS during Basic Training are considered PVT failures. Upon completion of PVT Phase II, and as specified, prepare and submit the PVT Phase II Report documenting any failures which occurred and repairs performed during PVT Phase II.

3.8 MAINTENANCE AND SERVICE

Perform inspection, testing, cleaning, and part or component replacement as specified and as required to maintain the warranty. Work includes providing necessary preventive and unscheduled maintenance and repairs to keep the UMCS operating as specified, and accepted by the Government, and other services as specified. Perform work in compliance with manufacturer's recommendations and industry standards. Provide technical support via telephone during regular working hours.

3.8.1 Work Coordination

Schedule and arrange work to cause the least interference with the normal Government business and mission. In those cases where some interference may be essentially unavoidable, coordinate with the Government to minimize the impact of the interference, inconvenience, equipment downtime, interrupted service and personnel discomfort.

3.8.2 Work Control

Upon completion of work on a system or piece of equipment, that system or piece of equipment must be free of missing components or defects which would prevent it from functioning as originally intended and designed. Replacements must conform to the same specifications as the original equipment. During and at completion of work, do not allow debris to spread unnecessarily into adjacent areas nor accumulate in the work area itself.

3.8.3 Working Hours

Working hours are from 7:30 A.M. to 4:00 P.M. local time Mondays through Fridays except Federal holidays.

3.8.4 Equipment Repairs

Initiate and complete equipment repairs within the following time periods, where time periods are measured as actual elapsed time from first notification, including working and non-working hours:

- a. for non-redundant computer server hardware, initiate within 4 hours and complete within 8 hours.
- b. for non-redundant computer workstation hardware, initiate within 4 hours and complete within 8 hours.
- c. for redundant computer server hardware, initiate within 36 hours and complete within 5 days.
- d. for redundant computer workstation hardware, initiate within 2 days and complete within 5 days.
- e. for active (powered) control hardware, initiate within 4 hours and complete within 6 hours.
- f. for cabling and other passive network hardware, initiate within 16 hours and complete within 5 days.

Repair is the restoration of a piece of equipment, a system, or a facility to such condition that it may be effectively used for its designated purposes. Repair may be overhaul, reprocessing, or replacement of nonfunctional parts or materials or replacement of the entire unit or system.

3.8.5 Replacement, Modernization, Renovation

The Government may replace, renovate, or install new equipment as part of the UMCS at Government expense and by means not associated with this contract without voiding the system warranty. Replaced, improved, updated, modernized, or renovated systems and equipment interfaced to the system may be added to the Contractor's maintenance and service effort as a modification.

3.8.6 Access To UMCS Equipment

Access to UMCS equipment must be in accordance with the following:

- a. Coordinate access to facilities and arrange that they be opened and closed during and after the accomplishment of the work effort. For access to a controlled facility contact the Government for assistance.
- b. The Government may provide keys for access to UMCS equipment where the Government determines such key issuance is appropriate. Establish and implement methods of ensuring that keys issued by the Government are not lost or misplaced, are not used by unauthorized persons, and are not duplicated.
- c. The Government may provide passwords or issue Common Access Cards (CAC) for access to UMCS computer equipment where the Government determines such issuance is appropriate. Establish and implement methods of ensuring that passwords and Common Access Cards issued by the Government are not used by unauthorized persons.

3.8.7 Records, Logs, and Progress Reports

Keep records and logs of each task, and organize cumulative chronological records for each major component, and for the complete system. Maintain a continuous log for the UMCS. Keep complete logs and be available for

inspection on site, demonstrating that planned and systematic adjustments and repairs have been accomplished for the UMCS.

3.8.8 Preventive Maintenance Requirements

Perform maintenance procedures as described below, or more often if required by the equipment manufacturer.

3.8.8.1 Preventive Maintenance Work Plan

Prepare a Preventive Maintenance Work Plan to schedule all required preventive maintenance. Obtain Government approval of the Work Plan as specified in paragraph PROJECT SEQUENCING. Strictly adhere to the approved work plan to facilitate Government verification of work.

3.8.8.2 Semiannual Maintenance

Perform the following Semiannual Maintenance as specified:

- a. Perform data backups on all Server Hardware.
- b. Run system diagnostics and correct diagnosed problems.
- c. Perform fan checks and filter changes for UMCS hardware.
- d. Perform all necessary adjustments on printers.
- e. Resolve all outstanding problems.
- f. Install new ribbons, ink cartridges and toner cartridges into printers, and ensure that there is at least one spare ribbon or cartridge located at each printer.

3.8.9 Service Call Reception

- a. A Government representative will advise the Contractor by phone or in person of all maintenance and service requests, as well as the classification of each based on the definitions specified. A description of the problem or requested work, date and time notified, location, classification, and other appropriate information will be placed on a Service Call Work Authorization Form by the Government.
- b. Submit procedures for receiving and responding to service calls during regular working hours. Provide a single telephone number for receipt of service calls during regular working hours; service calls are to be considered received at the time and date the telephone call is placed by the authorized Government representative.
- c. Separately record each service call request, as received on the Service Call Work Authorization form and complete the Service Call Work Authorization form for each service call. Include the following information in the completed form: the serial number identifying the component involved, its location, date and time the call was received, nature of trouble, names of the service personnel assigned to the task, instructions describing what has to be done, the amount and nature of the materials to be used, the time and date work started, and the time and date of completion.
- d. Respond to each service call request within two working hours.

Provide the status of any item of work within four hours of the inquiry during regular working hours, and within 16 hours after regular working hours or as needed to meet the Equipment Repair requirements as specified.

3.8.10 Service Call Work Warranty

Provide a 1 year unconditional warranty on service call work which includes labor and material necessary to restore the equipment involved in the initial service call to a fully operable condition. In the event that service call work causes damage to additional equipment, restore the system to full operation without cost to the Government. Provide response times for service call warranty work equivalent to the response times required by the initial service call.

3.8.11 System Modifications

Make recommendations for system modification in writing to the Government. Do not make system modifications without prior approval of the Government. Incorporate any modifications made to the system into the Operations and Maintenance Instructions, and any other documentation affected. Make available to the Government software updates for all software furnished under this specification during the life of this contract. Schedule at least one update near the end of the contract period, at which time make available the latest released version of all software provided under this specification, and install and validate it upon approval by the Government.

3.9 TRAINING

Conduct training courses for designated personnel in the maintenance, service, and operation of the system as specified, including specified hardware and software. The training must be oriented to the specific system provided under this contract. Provide audiovisual equipment and other training material and supplies required for the training. When training is conducted at Government facilities, the Government reserves the right to record the training sessions for later use. A training day is defined as 8 hours of classroom instruction, excluding lunchtime, Monday through Friday, during the daytime shift in effect at the training facility. For guidance in planning the required instruction, the Contractor should assume that attendees will be tradesmen such as electricians or boiler operators. Obtain approval of the training schedule from the Government at least 30 days prior to the first day of training.

3.9.1 Training Documentation

Prepare and submit one set of Training manuals for each of Basic Training Documentation, Advanced Training Documentation, and Refresher Training Documentation, where each set of documentation consists of:

3.9.1.1 Course Attendance List

Course Attendance List developed in coordination with and signed by the Controls shop supervisor.

3.9.1.2 Training Manuals

Include an agenda, defined objectives for each lesson, and a detailed

description of the subject matter for each lesson in the training manuals. Where portions of the course material are presented by audiovisuals, include copies of those audiovisuals as a part of the printed training manuals.

3.9.2 Basic Training

Conduct a Basic Training course at the project site on the installed system for a period of no less than 5 training days during Phase 2 of the PVT. A maximum of ten personnel will attend this course. Design training targeted towards training personnel in the day-to-day operation and basic maintenance of the system. Upon completion of this course, each student, using appropriate documentation, should be able to start the system, operate the system, recover the system after a failure, perform routine maintenance and describe the specific hardware architecture and operation of the system. Include the following topics at a minimum:

- a. General system architecture.
- b. Functional operation of the system, including workstations and system navigation.
- c. System start-up procedures.
- d. Failure recovery procedures.
- e. Schedule configuration.
- f. Trend configuration.
- g. Perform point overrides and override release.
- h. Reports generation.
- i. Alarm reporting and acknowledgements.
- j. Diagnostics.
- k. Historical files.
- l. Maintenance procedures:
 - (1) Physical layout of each piece of hardware.
 - (2) Troubleshooting and diagnostic procedures.
 - (3) Preventive maintenance procedures and schedules.

3.9.3 Advanced Training

Conduct an Advanced Operator Training course at the project site for a period of not less than five days. A maximum of ten personnel will attend this course. Structure the course to consist of "hands-on" training under the constant monitoring of the instructor. Include training on the M&C Software, and the BACnet Network Browser. Upon completion of this course, the students should be fully proficient in the operation and management of all system operations and must be able to perform all tasks required to integrate a field control system into the UMCS. Report the skill level of each student at the end of this course. Include the following topics at a

minimum:

- a. A review of all topics in Basic Training
- b. Using the BACnet Network Browser for network discovery
- c. M&C Software configuration, including but not limited to: creating and editing system displays, alarms, schedules, trends, demand limiting and calculations.

3.9.4 Refresher Training

Conduct a Refresher Training course at the project site for a period of two training days when approved by the Government and as specified in paragraph PROJECT SEQUENCING. A maximum of ten personnel will attend the course. Structure the course to address specific topics that the students need to discuss and to answer questions concerning the operation of the system. Upon completion of the course, the students should be fully proficient in system operation and have no unanswered questions regarding operation of the installed UMCS. Correct any system failures discovered during the Refresher Training at no cost to the Government.

APPENDIX A

<u>QC CHECKLIST</u>	
This checklist is not all-inclusive of the requirements of this specification and should not be interpreted as such.	
This checklist is for (check one:)	
Pre-Construction QC Checklist Submittal (Items 1-2)	()
Post-Construction QC Checklist Submittal (Items 1-6)	()
Close-out QC Checklist Submittal (Items 1-14)	()
Instructions: Initial each item in the space provided (____) verifying that the requirement has been met.	
Verify the following items for Pre-Construction, Post-Construction and Closeout QC Checklist Submittals:	
1	Contractor Design Drawing Riser Diagram includes location and types of all Control Hardware and Computer Hardware.
2	M&C Software supports , and ASHRAE 135, and MODBUS Protocol/ MODBUS TCP/IP, and OPC DA. M&C Software is BTL Listed as a B-AWS.
Verify the following items for Post-Construction and Closeout QC Checklist Submittal:	
3	Communication between the M&C Software and ASHRAE 135 field control systems uses only ASHRAE 135. Communication between the M&C Software and MODBUS Protocol/MODBUS TCP/IP field control systems uses only MODBUS Protocol/MODBUS TCP/IP. Communication between the M&C Software and OPC DA field control systems uses only OPC DA.

<u>QC CHECKLIST</u>		
4	Connections to non-ASHRAE 135, non-Modbus, non-OPC DA field control systems are via a Gateway from the field control system to ASHRAE 135 or to Modbus, or to OPC DA, or via a UMCS supported protocol without the use of a hardware Gateway.	___
5	Computer workstations and servers are installed as shown on the UMCS Riser Diagram.	___
6	Training schedule and course attendee lists have been developed and coordinated with shops and submitted.	___
Verify the following items for Closeout QC Checklists Submittal:		
7	All points in field control systems have been discovered and are available at the M&C Software.	___
8	All software has been licensed to the Government.	___
9	M&C software monitoring displays have been created for all building systems, including all override and display points indicated on Points Schedule drawings.	___
10	Final As-built Drawings accurately represent the final installed system.	___
11	Default trends have been set up (per Points Schedule drawings).	___
12	Scheduling has been configured at the M&C Software (per Occupancy Schedule drawing).	___
13	O&M Instructions have been completed and submitted.	___

<u>QC CHECKLIST</u>	
14	Basic Operator and Advanced Training courses have been completed. ____

(QC Representative Signature)	(Date)

-- End of Section --

SECTION 26 05 19.00 10

INSULATED WIRE AND CABLE

11/22

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 1202 (2006; R 2012; CORR 1 2012)
Flame-Propagation Testing of Wire and Cable

INSULATED CABLE ENGINEERS ASSOCIATION (ICEA)

ICEA S-58-679 (2014) Control, Instrumentation and
Thermocouple Extension Conductor
Identification

ICEA T-30-520 (1986) Conducting Vertical Cable Tray
Flame Tests with Theoretical Heat Input
Rate of 70,000 B.T.U./Hour

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI/NEMA WC 71/ICEA S-96-659 (2014; R 2022) Standard for Nonshielded
Cables Rated 2001-5000 Volts for use in
the Distribution of Electric Energy

NEMA WC 26 (2008) Binational Wire and Cable Packaging
Standard

NEMA WC 57 (2014) Standard for Control, Thermocouple
Extension, and Instrumentation Cables

NEMA WC 70 (2021) Power Cable Rated 2000 Volts or
Less for the Distribution of Electrical
Energy

NEMA WC 74/ICEA S-93-639 (2022) 5-46 kV Shielded Power Cable for
Use in the Transmission and Distribution
of Electric Energy

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National
Electrical Code

UNDERWRITERS LABORATORIES (UL)

UL 83 (2017; Reprint Mar 2020) UL Standard for
Safety Thermoplastic-Insulated Wires and
Cables

UL 1685	(2015) UL Standard for Safety Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables
UL 2556	(2015) UL Standard for Safety Wire and Cable Test Methods

1.2 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability Notebook, in conformance to Section 01 33 00 Submittal Procedures. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Wire and Cable; G

Conductors; G

Cable Manufacturing Data

SD-06 Test Reports

Test Report(s), Inspection Report(s), and Verification Report(s); G

1.3 DELIVERY, STORAGE, AND HANDLING

Furnish cables on reels or coils. Each cable and the outside of each reel or coil, must be plainly marked or tagged to indicate the cable length, voltage rating, conductor size, and manufacturer's lot number and reel number. Each coil or reel of cable must contain only one continuous cable without splices. Cables for exclusively dc applications, as specified in paragraph "High-Voltage Test Source," must be identified as such. Shielded cables rated 2,001 volts and above must be reeled and marked in accordance with NEMA WC 26, as applicable. Reels must remain the property of the Government.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Wire Table

Furnish wire and cable in accordance with the requirements of the wire table below, conforming to the detailed requirements specified herein.

2.1.2 Rated Circuit Voltages

All power wire and cable must have minimum rated circuit voltages in accordance with NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639 as applicable. Power wire and cable for circuit voltages rated 0-600 volts must be rated not less than 600 volts. Control wire and cable must have minimum rated circuit voltages in accordance with NEMA WC 57, but must be rated 600 volts if routed in raceway with other

conductors that are rated 600 volts.

2.1.3 Conductors

2.1.3.1 Material for Conductors

Conductors must conform to all the applicable requirements of NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639 as applicable. Copper conductors must be annealed copper material and they may be bare, or tin- or lead-alloy-coated, if required by the type of insulation used.

2.1.3.2 Size

Minimum wire size must be as listed below.

- a. No. 12 AWG for power and lighting circuits
- b. No. 10 AWG for current transformer secondary circuits
- c. No. 14 AWG for potential transformer, relaying, and control circuits
- d. No. 16 AWG for annunciator circuits
- e. No. 19 AWG for alarm circuits

Minimum wire sizes for rated circuit voltages of 2,001 volts and above must not be less than those listed for the applicable voltage in ANSI/NEMA WC 71/ICEA S-96-659 or NEMA WC 74/ICEA S-93-639, as applicable.

2.1.3.3 Stranding

Conductor stranding classes cited herein must be as defined for control conductors in NEMA WC 57 or as defined for 0-2,000 volts power conductors in NEMA WC 70, as applicable. Lighting conductors No. 10 AWG and smaller must be solid or have Class B stranding. Any conductors used between stationary and moving devices, such as hinged doors or panels, must have Class H or K stranding. All other conductors must have Class B or C stranding, except that conductors as shown, or in the schedule, as No. 12 AWG may be 19 strands of No. 25 AWG, and conductors shown as No. 10 AWG may be 19 strands of No. 22 AWG. Conductor stranding classes for circuit voltages 2,001 volts and above must be as defined in ANSI/NEMA WC 71/ICEA S-96-659 and NEMA WC 74/ICEA S-93-639, as applicable.

2.1.3.4 Conductor Shielding

Use conductor shielding conforming to NEMA WC 57 for control wire and cable as applicable. Use conductor shielding conforming to ANSI/NEMA WC 71/ICEA S-96-659 or NEMA WC 74/ICEA S-93-639, as applicable, on power cables having a rated circuit voltage above 2,000 volts.

2.1.3.5 Separator Tape

Where conductor shielding, strand filling, or other special conductor treatment is not required, a separator tape between conductor and insulation is permitted.

2.1.4 Insulation

2.1.4.1 Insulation Material

Unless specified otherwise or required by NFPA 70, wires in conduit, other than service entrance, must be 600-volt, Type THWN/THHN conforming to UL 83. Insulation for control wire and cable must meet the requirements of NEMA WC 57. Insulation requirements for wire and cable rated less than 2,000 volts must meet the requirements of NEMA WC 70. Insulation requirements for wire and cable rated 2,001-5,000 volts must meet the requirements of ANSI/NEMA WC 71/ICEA S-96-659. Insulation requirements for wire and cable rated 5,001 volts and greater must meet the requirements of NEMA WC 74/ICEA S-93-639.

For shielded cables of rated circuit voltages above 2,000 volts, the following provisions must also apply:

- a. XLPE, if used, must be tree-retardant.
- b. Insulation must be chemically bonded to conductor shielding.
- c. The insulation material and its manufacturing, handling, extrusion and vulcanizing processes must all be subject to strict procedures to prevent the inclusion of voids, contamination, or other irregularities on or in the insulation. Insulation material must be inspected for voids and contaminants.
- d. Cables with repaired insulation defects discovered during factory testing, or with splices or insulation joints, are prohibited unless specifically approved.

2.1.4.2 Insulation Thickness

The insulation thickness for each conductor must be based on its rated circuit voltage.

2.1.4.2.1 Power Cables, 2,000 Volts and Below

The insulation thickness for single-conductor and multiple-conductor power cables rated 2,000 volts and below must be as required by NEMA WC 70, as applicable. Some thicknesses of NEMA WC 70 will be permitted only for single-conductor cross-linked thermosetting polyethylene insulated cables without a jacket. NEMA WC 70 ethylene-propylene rubber-insulated conductors must have a jacket.

2.1.4.2.2 Single-Conductor and Multiple-Conductor Control Cables

The insulation thickness of control conductor sizes 22 AWG to 10 AWG used for control and related purposes must be as required by NEMA WC 57, as applicable. Control conductors larger than 10 AWG must be as required by NEMA WC 70.

2.1.5 Jackets

All cables must have jackets meeting the requirements of NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, and NEMA WC 74/ICEA S-93-639, as applicable, and as specified herein. Individual conductors of multiple-conductor cables must be required to have jackets only if they are necessary for the conductor to meet other specifications herein.

Jackets of single-conductor cables and of individual conductors of multiple-conductor cables, except for shielded cables, must be in direct contact and adhere or be vulcanized to the conductor insulation. Multiple-conductor cables and shielded single-conductor cables must be provided with a common overall jacket, which must be tightly and concentrically formed around the core. Repaired jacket defects found and corrected during manufacturing are permitted if the cable, including jacket, afterward fully meets these specifications and the requirements of the applicable standards.

2.1.5.1 Jacket Material

The jacket must be one of the materials listed below. Polyvinyl chloride compounds will not be permitted. Variations from the materials required below will be permitted only if approved for each specific use, upon submittal of sufficient data to prove that they exceed all specified requirements for the particular application.

2.1.5.1.1 General Use

Heavy-duty black neoprene	NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639
Heavy-duty chlorosulfonated polyethylene	NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639
Heavy-duty cross-linked (thermoset) chlorinated polyethylene	NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639

2.1.5.1.2 Accessible Use Only, 2,000 Volts or Less

Cables installed where they are entirely accessible, such as cable trays and raceways with removable covers, or where they pass through less than 10 feet of exposed conduit only, must have jackets of one of the materials in item "a. General Use" or one of the following:

General-purpose neoprene	NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639
Black polyethylene (MDPE)	NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639
Thermoplastic chlorinated polyethylene	NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639

2.1.5.2 Jacket Thickness

The minimum thickness of the jackets must be not less than 80 percent of the respective nominal thicknesses specified below.

2.1.5.2.1 Multiple-Conductor Cables

Thickness of the jackets of the individual conductors of multiple-conductor cables must be as required by NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639 as applicable and must be in addition to the conductor insulation thickness required by the applicable respective NEMA publication for the insulation used.

Thickness of the outer jackets and associated coverings of the assembled multiple-conductor cables must be as required by NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639 as applicable.

2.1.5.2.2 Single-Conductor Cables

Single-conductor cables must have a jacket thickness as specified in NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639 as applicable.

2.1.6 Metal-Clad Cable

2.1.6.1 General

The metallic covering or sheath must be interlocked metal tape or continuous corrugated metal, conforming to the applicable requirements of NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639. The type of metal for the metallic covering must be galvanized steel. If the covering is of ferrous metal, it must be galvanized. Grounding conductor(s) conforming to NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639 as applicable must be furnished for each multiple-conductor metal-clad cable. Assembly and cabling must be as specified in paragraph "Cabling." The metallic covering must be applied over an inner jacket or filler tape. The cable must be assembled so that the metallic covering will be tightly bound over a firm core.

2.1.6.2 Jackets

Metal-clad cables may have a jacket under the armor, and must have a jacket over the armor. Jackets must comply with the requirements of NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639 as applicable. The outer jacket for the metal-clad cable may be of polyvinyl chloride (PVC) only if specifically approved.

2.1.7 Multiple-Conductor Cables

Grounding conductor(s) conforming to NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639 as applicable must be furnished for each multiple-conductor cable. Assembly and cabling must be as specified in paragraph CABLING.

2.2 CABLE IDENTIFICATION

2.2.1 Color-Coding

Insulation of individual conductors of multiple-conductor cables must be color-coded in accordance with ICEA S-58-679, except that colored braids will not be permitted. Only one color-code method must be used for each cable construction type. Control cable color-coding must be as indicated. Power cable color-coding must be as follows:

- a. 208/120 volt, three-phase
 - (1) Phase A - black
 - (2) Phase B - red
 - (3) Phase C - blue
 - (4) Grounded neutral - white
 - (5) Insulated grounding conductor - green
- b. 480/277 volt, three-phase
 - (1) Phase A - brown
 - (2) Phase B - orange
 - (3) Phase C - yellow
- c. 240/120 volt, single phase: Black and red

Other individual conductors must be color-coded as indicated, but such color-coding may be accomplished by applying colored plastic tapes or colored sleeves at terminations.

2.2.2 Cabling

Individual conductors of multiple-conductor cables must be assembled with flame-and moisture-resistant fillers, binders, and a lay conforming to NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639. Flat twin cables are prohibited. Fillers must be used in the interstices of multiple-conductor round cables with a common covering where necessary to give the completed cable a substantially circular cross section. Fillers must be non-hygroscopic material, compatible with the cable insulation, jacket, and other components of the cable. The rubber-filled or other approved type of binding tape must consist of a material that is compatible with the other components of the cable and must be lapped at least 10 percent of its width.

2.2.3 Dimensional Tolerance

The outside diameters of single-conductor cables and of multiple-conductor cables must not vary more than 5 percent and 10 percent, respectively, from the manufacturer's published catalog data.

PART 3 EXECUTION

3.1 INSTALLATION INSTRUCTIONS

Submit cable manufacturing data. The following information must be provided by the cable manufacturer for each size, conductor quantity, and type of cable furnished:

- a. Minimum bending radius, in inches - For multiple-conductor cables, this information must be provided for both the individual conductors and the multiple-conductor cable.
- b. Pulling tension and sidewall pressure limits, in pounds.
- c. Instructions for stripping semiconducting insulation shields, if furnished, with minimum effort without damaging the insulation.
- d. Upon request, compatibility of cable materials and construction with specific materials and hardware manufactured by others must be stated. Also, if requested, recommendations must be provided for various cable operations, including installing, splicing, terminating, etc.

3.2 TEST REPORT(S), INSPECTION REPORT(S), AND VERIFICATION REPORT(S)

3.2.1 Cable Data

Do not begin any wire and cable fabrication until materials are submitted and approved by the Contracting Officer. Submit cable data for approval including, but not limited to, dimensioned sketches showing cable construction and sufficient additional data to show that wire and cable meet the requirements of this Section.

3.2.2 Inspection and Tests

Inspection and tests of wire and cable furnished under these specifications must be made by and at the plant of the manufacturer, and must be witnessed by the Contracting Officer, unless waived in writing. The Government may require or perform further tests before or after installation. Testing in general must comply with NEMA WC 57, NEMA WC 70, ANSI/NEMA WC 71/ICEA S-96-659, or NEMA WC 74/ICEA S-93-639 as applicable. Specific tests required for particular materials, components, and completed cables must be as specified in the sections of the above standards applicable to those materials, components, and cable types. Tests must also be performed in accordance with the additional requirements specified below. Submit certified copies of test reports.

3.2.2.1 High-Voltage Test Source

Where the applicable standards allow a choice, high-voltage tests for cables to be used exclusively on dc circuits must be made with dc test voltages. Cables to be used exclusively on ac circuits must be tested with ac test voltages. If both ac and dc will be present, on either the same or separate conductors of the cable, ac test voltages must be used.

3.2.2.2 Flame Tests

All multiple-conductor and single-conductor cable assemblies must pass either the vertical cable tray flame tests required by ICEA T-30-520

(stated in, but not required by NEMA WC 70); the vertical tray flame propagation test requirements of UL 1685 Method 1; the vertical tray flame propagation test requirements of UL 1685 FT4 and IEEE 1202; the wire and cable burning characteristics test of the UL 2556 VW-1 Test; or (for control cables only) the flame test as required by NEMA WC 57. If such tests, however, have previously been made on identical cables, these tests need not be repeated. Instead, certified reports of the original qualifying tests must be submitted. In this case the reports furnished under paragraph "Reports," must include information, identify critical information, and verify that all of each cable's materials, construction, and dimensions are the same as those in the qualifying tests.

3.2.2.3 Independent Tests

The Government may make visual inspections, continuity or resistance checks, insulation resistance readings, power factor tests, or dc high potential tests at field test values. A cable's failure to pass these tests and inspections, or failure to produce readings consistent with acceptable values for the application, will be grounds for rejection of the cable.

3.2.2.4 Reports

Furnish results of tests. No wire or cable must be shipped until authorized. Lot number and reel or coil number of wire and cable tested must be indicated on the test reports.

WIRE TABLE						
Item No.	Size, AWG or kcmil	No. of Conds.	Rated Circuit Voltage	Stranding	Comments	Quantity, lin ft

-- End of Section --

SECTION 26 05 73

POWER SYSTEM STUDIES
08/23

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

- | | |
|-------------|--|
| IEEE 1584 | (2018; E 2019) Guide for Performing Arc-Flash Hazard Calculations |
| IEEE 1584.1 | (2022) Guide for the Specification of Scope and Deliverable Requirements for an Arc-Flash Hazard Calculation Study |
| IEEE 3002.2 | (2018) Recommended Practice for Conducting Load-Flow Studies and Analysis of Industrial and Commercial Power Systems |
| IEEE 3002.3 | (2018) Recommended Practice for Conducting Short-Circuit Studies and Analysis of Industrial and Commercial Power Systems |
| IEEE C2 | (2023) National Electrical Safety Code |

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- | | |
|----------|--|
| NFPA 70E | (2024) Standard for Electrical Safety in the Workplace |
|----------|--|

U.S. DEPARTMENT OF DEFENSE (DOD)

- | | |
|--------------|--|
| UFC 3-560-01 | (2017; with Change 3, 2023) Operation and Maintenance: Electrical Safety |
|--------------|--|

1.2 SYSTEM DESCRIPTION

The power system covered by this specification consists of: all electrical distribution equipment downstream of the service transformer's secondary connection points.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability Notebook, in conformance to Section 01 33 00 Submittal Procedures. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Field Examination Plan; G

Arc Flash Label Formats; G

SD-06 Test Reports

Field Examination

SD-07 Certificates

System Analyzer; G

SD-11 Closeout Submittals

Model Files; G

Load Flow Study; G

Fault Current Study; G

System Coordination Study; G

Arc Flash Hazard Study; G

1.4 QUALITY ASSURANCE

1.4.1 System Analyzer

The System Analyzer must perform the power system studies. The System Analyzer must be a registered professional electrical engineer with a minimum of 3 years of experience with power system studies. Include a list of three comparable jobs performed by the System Analyzer with specific names and telephone numbers for reference. Include the license number and state of the registered Professional Engineer.

1.4.2 System Verifier

The System Verifier may inspect and record settings, markings, and otherwise document the existing equipment. The System Verifier may also place appropriate hazard labels on equipment. The System Verifier must not make any calibrations or adjustments or place equipment into service. When working with energized equipment, the system verifier must be a Qualified Person per NFPA 70E or working under the direct supervision of a Qualified Person. The System Verifier may communicate with the system owner to determine if the equipment within the studied system has received maintenance and testing in accordance with NETA MTS or NFPA 70B.

PART 2 PRODUCTS

Not used.

PART 3 EXECUTION

3.1 FIELD EXAMINATION

For each pre- and post-study inspection, submit a field examination plan identifying which facilities must be examined to complete the required work. Include a complete information verification procedure, where

Qualified Personnel will be required, PPE requirements for "live" equipment examinations, and equipment to be used within the limited approach boundary of the equipment.

3.1.1 General

Perform field inspections of the site and equipment before the first study and after the last study to determine the state and settings of the equipment and to verify the final settings agree with the studies. The post-study inspection may be performed by the testing organization approved in 26 08 00 APPARATUS INSPECTION AND TESTING.

Schedule the field examination by the System Verifier with the Contracting Officer at least 10 business days before conducting examination. Furnish all materials, labor, and equipment necessary to conduct the examination. Maintain a written record of the all equipment examined, equipment location, equipment ratings, settings, personnel involved, and the date the examination was performed. Submit the written record of each field examination.

3.1.2 Safety

Where examination of the equipment requires energized equipment to be opened, provide a Qualified Person to directly supervising any non-Qualified Person within the hazard area. Use PPE, protective barriers, danger signs and other safety devices to protect and warn personnel in the vicinity of "live" equipment being examined.

3.1.3 Application of Arc Flash Labels

Install arc flash warning labels using Qualified Personnel as necessary after the setting and inspection is complete. For new or modified equipment, install labels before the equipment is energized for the first time after installation/modification or setting changes. Schedule the label placement with the Contracting Officer at least 5 business days before label placement. Furnish all materials, labor, and equipment necessary to place the labels. Maintain a written record of the all equipment that received labels, personnel involved, and the date labels were placed.

3.2 POWER SYSTEM STUDIES

Perform power system studies to demonstrate that the equipment selected and system constructed meet the contract requirements for fault current and interrupt ratings, coordination, protection, and Arc Flash Hazard. Submit reports of the studies along with protective device equipment submittals. Apply Arc Flash Hazard labels to equipment after the studies are approved. Update and resubmit the studies after any changes to the equipment or systems which may affect the study results, and re-apply Arc Flash Hazard labels to equipment after the resubmitted studies are approved. The Government is not responsible for any changes to equipment, device ratings, settings, or additional labor for installation of equipment or devices or labels ordered and/or procured before approval of the study.

3.2.1 Scope of Studies

The scope of the studies must begin at the utility service entrance of a building and extend down to load buses/panels where the fault current is 2,000 amperes or less (symmetrical) for distribution buses nominally operating at 208 volt AC and above.

The "source bus" is the source of energy for system being analyzed. This may be the energy feed from a utility, the first bus upstream of the work, generators within the work or upstream of the work, or any other source capable of contributing significant energy into the system being analyzed.

In the systems model for the studies, incorporate all existing and new equipment within the scope of the studies. Incorporate any additional sources or load equipment necessary to accurately model the system's performance.

Where multiple sources of power may be in service in various combinations or where electrical loops are in the system, incorporate into the studies all the modes of operation to evaluate the impact of the modes of operation on the system.

3.2.2 Determination of Facts

Determine and document the time-current characteristics, features, ratings, ampacities, and nameplate data for each existing protective device, electrical equipment, and feeder cables. Obtain the available fault current from the owner of the source bus. For multiple modes of operation, use the mode with available fault current that produces the greatest incident energies in the arc flash hazard study.

Utilize field-verified data in the power system studies. Document the field-verified data in the report.

3.2.3 Single Line Diagram

Provide a single line diagram showing the electrical system buses, devices, transformation points, and all sources of load current and fault current, including generator and motor contributions. Provide a diagram from the system model. Each bus, device or transformation point must have a unique identifier. Show the location of switches, breakers, and circuit interrupting devices on the diagram together with available fault data, and the device interrupting rating.

The naming of existing components within the system model and single line diagram must match existing installed equipment names. The naming of new components within the system model and single line diagram must use unique identifiers and be coordinated with the Government.

3.2.4 Load Flow Study

Perform the load flow study in accordance with IEEE 3002.2 to identify initial steady-state conditions for the fault current study. For each operating scenario, provide load flow results on the diagram or in the report. Show or describe the loading factors and assumptions used in each operating mode.

3.2.5 Fault Current Study

Use the results of the load flow study to perform the fault current study in accordance with IEEE 3002.3. Provide balanced three-phase fault, bolted line-to-line fault, and single line-to-ground fault current values at each voltage transformation point and at each power distribution bus. For each location, show in tabular form on the diagram or in the report the maximum and minimum available fault currents of all modes of operation for that location.

Where the available fault current at the source bus is not available, describe how the fault contribution from the source bus was determined and why this method is reasonable for the study.

3.2.6 System Coordination Study

Use the results of the load flow study and fault current study. For normal modes of operation, demonstrate that selectivity has been obtained between the devices within the scope of the project. Demonstrate the equipment, machines, and conductors are protected from damage from overloads and fault conditions. Include a description of the coordination of the protective devices in this project. Provide a written narrative describing which devices may operate in the event of a fault at each bus; the logic used to arrive at device ratings and settings; situations where system coordination is not achievable due to device limitations; coordination between upstream and downstream devices; and relay settings. Provide recommendations to improve or enhance system reliability, and detail where such changes would involve additions or modifications to the contract and cost damages (addition or reduction). Provide composite coordination plots on a log-log scale. Where recommendations are provided to improve or enhance system reliability, provide separate coordination plots on log-log scale showing the system coordination before and after the implementation of the recommendations. Where coordination has been adjusted to lower arc flash values, include a discussion of the change and the impact on the system within the report.

3.2.7 Arc Flash Hazard Study

Perform the arc flash hazard study in accordance with IEEE 1584.1. Utilize the data from the fault current study to determine the worst case incident energy per IEEE 1584, IEEE C2, and OSHA 29 CFR 1910.269 Appendix E. Use identified modes of operation to determine the worst case arc flash energy. If not included in another study, include a description of the devices and device settings for the operating modes that provided the highest arc flash energy. Where the adjusting the coordination of devices to obtain lower arc flash values, include a discussion of the change and the impact on the system within the report. Where the arc flash energies exceed 8 cal/cm^2 provide recommendations to reduce the arc flash energy to 4 cal/cm^2 .

3.2.8 Study report(s)

- a. Include a narrative describing the studies performed; the bases and methods used; and the desired method of coordinated protection of the power system.

- b. Include descriptive and technical data for existing devices and new protective devices proposed. Include manufacturers published data, nameplate data, and definition of the fixed or adjustable features of the existing or new protective devices. For existing devices, included statements on the condition of the equipment based upon field inspections and owner's statements and reports.
- c. Document utility company data including system voltages, fault MVA, system X/R ratio, time-current characteristic curves, current transformer ratios, and relay device numbers and settings. Identify all assumptions about the protection devices, equipment, and system where data was not available.
- d. For each bus in the system, provide fully coordinated composite time-current characteristics (TCC) curves as required to ensure coordinated power system protection between protective devices and equipment. In a tabular format, provide recommended ratings and settings of all protective devices.
- e. Provide an arc flash study report in accordance with IEEE 1584.1.
- f. Provide the calculations performed for the studies, including computer programs utilized. Provide the name of the software package, developer, and version number.
- f. The System Analyzer must stamp the study reports.

3.2.9 Arc Flash Labels

Provide arc flash warning labels on electrical equipment likely to require examination, servicing, or maintenance while energized. Typical types of equipment include pad-mounted transformers, switchgear, switchboards, panelboards, disconnect switches, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling occupancies. The arc flash label naming must match the naming used in the system modeling and the single line diagram.

Comply with the label requirements specified in UFC 3-560-01. Obtain approval of arc flash label formats before printing.

- a. Provide a 3.5 inch x 5 inch to 4 inch x 6 inch thermal transfer type label of high adhesion polyester for each location device analyzed. The label must remain in place and be legible for at least 5 years in the installed environment.
- b. Labels must be machine printed with no field markings. Provide arc flash labels in the following manner. All labels must be based on implemented overcurrent devices and settings.
 - 1. Provide at least one arc flash label for each 480 volt and 208 volt panelboards.
 - 2. Provide at least one arc flash label for each low voltage (less than 1000 V) switchboard.
 - 3. Where the equipment construction has different hazards levels in different areas, provide a label for each compartment, cubicle, or section separated by barriers.

- c. Use the worst case hazard of all operating scenarios unless mitigation procedures are used. If mitigation procedures are used, explain the procedures on the label.

3.3 MODELING

Develop a software model of the electrical system identified in the scope of the studies. Use the latest version of SKM PowerTools(TM), EasyPower(TM), or ETAP(TM). Develop the model with accurate, verified information. Model existing electrical equipment, machines, devices, and conductors directly connected to, altered by, or otherwise affected by the work. This includes, but is not limited to generators, transformers, switchgear, switchboards, panelboards, motor control centers, motors, voltage regulators, tap changers, protective relays, circuit breakers, switches, fuses, conductors, capacitors, reactors, grounding system, and control equipment.

Provide the final model files in their native editable formats for future use by the Government. Include device information for devices not in the software vendor's standard distribution.

-- End of Section --

SECTION 26 08 00

APPARATUS INSPECTION AND TESTING

11/22

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS (2021) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

1.2 RELATED REQUIREMENTS

Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM applies to this section with additions and modifications specified herein.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-06 Test Reports

Acceptance Tests and Inspections; G

SD-07 Certificates

Qualifications of Organization, and Lead Engineering Technician; G

Acceptance Test and Inspections Procedure; G

1.4 QUALITY ASSURANCE

1.4.1 Qualifications

Engage the services of a qualified testing organization to provide inspection, testing, calibration, and adjustment of the electrical distribution system and generation equipment listed in paragraph ACCEPTANCE TESTS AND INSPECTIONS herein. Organization must be independent of the supplier, manufacturer, and installer of the equipment. The organization must be a first tier subcontractor. No work required by this section of the specification may be performed by a second tier subcontractor.

- a. Submit name and qualifications of organization. Organization must have been regularly engaged in the testing of electrical materials,

devices, installations, and systems for a minimum of 5 years. The organization must have a calibration program, and test instruments used must be calibrated in accordance with NETA ATS.

- b. Submit name and qualifications of the lead engineering technician performing the required testing services. Include a list of three comparable jobs performed by the technician with specific names and telephone numbers for reference. Testing, inspection, calibration, and adjustments must be performed by an engineering technician, certified by NETA (Level III) or the National Institute for Certification in Engineering Technologies (NICET) with a minimum of 5 years' experience inspecting, testing, and calibrating electrical distribution and generation equipment, systems, and devices.

1.4.2 Acceptance Tests and Inspections Reports

Submit certified copies of inspection reports and test reports. Include certification of compliance with specified requirements, identify deficiencies, and recommend corrective action when appropriate. Type and neatly bind test reports to form a part of the final record. Submit test reports documenting the results of each test not more than 10 days after test is completed.

1.4.3 Acceptance Test and Inspections Procedure

Submit test procedure reports for each item of equipment to be field tested at least 45 days prior to planned testing date. Do not perform testing until after test procedure has been approved.

PART 2 PRODUCTS

Not used.

PART 3 EXECUTION

3.1 ACCEPTANCE TESTS AND INSPECTIONS

Testing organization will perform acceptance tests and inspections. Test methods, procedures, and test values must be performed and evaluated in accordance with NETA ATS, the manufacturer's recommendations, and paragraph FIELD QUALITY CONTROL of each applicable specification section. Tests identified as optional in NETA ATS are not required unless otherwise specified. Place equipment in service only after completion of required tests and evaluation of the test results have been completed. Supply to the testing organization complete sets of shop drawings, settings of adjustable devices, and other information necessary for an accurate test and inspection of the system prior to the performance of any final testing. Notify Contracting Officer at least 14 days in advance of when tests will be conducted by the testing organization. Perform acceptance tests and inspections on applicable equipment and systems specified in the following sections:

- a. Section 26 24 13 SWITCHBOARDS
- b. Section 26 35 43 400 HERTZ ((HZ) SOLID STATE FREQUENCY CONVERTER. The NETA ATS representative must coordinate with the Contractor and the Converter Manufacturers' representative to witness, document, and validate the Converter Field Quality Control, Inspection and Testing. These tests will be performed by the converter manufacturers'

representative, however include the documentation in the overall NETA report as well.

3.2 SYSTEM ACCEPTANCE

Final acceptance of the system is contingent upon satisfactory completion of acceptance tests and inspections.

3.3 PLACING EQUIPMENT IN SERVICE

A representative of the approved testing organization must be present when equipment tested by the organization is initially energized and placed in service.

-- End of Section --

SECTION 26 20 00

INTERIOR DISTRIBUTION SYSTEM

08/23

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.1 (2014; Errata 2016) Electric Meters - Code for Electricity Metering

ASTM INTERNATIONAL (ASTM)

ASTM B1 (2013) Standard Specification for Hard-Drawn Copper Wire

ASTM B8 (2023) Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

ASTM D709 (2017) Standard Specification for Laminated Thermosetting Materials

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 81 (2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

IEEE Stds Dictionary (2009) IEEE Standards Dictionary: Glossary of Terms & Definitions

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS (2021) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION (NECA)

NECA NEIS 1 (2015) Standard for Good Workmanship in Electrical Construction

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C80.1 (2020) American National Standard for Electrical Rigid Steel Conduit (ERSC)

ANSI C80.3 (2020) American National Standard for Electrical Metallic Tubing (EMT)

ANSI C80.5	(2020) American National Standard for Electrical Rigid Aluminum Conduit
NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA FU 1	(2012) Low Voltage Cartridge Fuses
NEMA ICS 1	(2022) Standard for Industrial Control and Systems: General Requirements
NEMA ICS 2	(2000; R 2020) Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 V
NEMA ICS 4	(2015) Application Guideline for Terminal Blocks
NEMA ICS 6	(1993; R 2016) Industrial Control and Systems: Enclosures
NEMA KS 1	(2013) Enclosed and Miscellaneous Distribution Equipment Switches (600 V Maximum)
NEMA MG 1	(2021) Motors and Generators
NEMA RN 1	(2005; R 2013) Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
NEMA ST 20	(2014) Dry-Type Transformers for General Applications
NEMA TC 2	(2020) Standard for Electrical Polyvinyl Chloride (PVC) Conduit
NEMA TC 3	(2021) Polyvinyl Chloride (PVC) Fittings for Use With Rigid PVC Conduit and Tubing
NEMA WD 1	(1999; R 2020) Standard for General Color Requirements for Wiring Devices
NEMA WD 6	(2021) Wiring Devices Dimensions Specifications
NEMA Z535.4	(2023) Product Safety Signs and Labels
NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)	
NFPA 70	(2023; ERTA 7 2023; TIA 23-15) National Electrical Code
NFPA 70E	(2024) Standard for Electrical Safety in the Workplace
NFPA 780	(2023) Standard for the Installation of Lightning Protection Systems

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-568.1	(2020e) Commercial Building Telecommunications Infrastructure Standard
TIA-569	(2019e; Add 1 2022) Telecommunications Pathways and Spaces
TIA-607	(2019d) Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

10 CFR 431	Energy Efficiency Program for Certain Commercial and Industrial Equipment
29 CFR 1910.147	The Control of Hazardous Energy (Lock Out/Tag Out)
29 CFR 1910.303	Electrical, General

UNDERWRITERS LABORATORIES (UL)

UL 1	(2005; Reprint Jan 2022) UL Standard for Safety Flexible Metal Conduit
UL 4	(2004; Reprint Mar 2021) UL Standard for Safety Armored Cable
UL 6	(2022) UL Standard for Safety Electrical Rigid Metal Conduit-Steel
UL 6A	(2008; Reprint Mar 2021) UL Standard for Safety Electrical Rigid Metal Conduit - Aluminum, Red Brass, and Stainless Steel
UL 20	(2018; Reprint May 2023) UL Standard for Safety General-Use Snap Switches
UL 44	(2018; Reprint May 2021) UL Standard for Safety Thermoset-Insulated Wires and Cables
UL 50	(2024) UL Standard for Safety Enclosures for Electrical Equipment, Non-Environmental Considerations
UL 67	(2018; Reprint Aug 2023) UL Standard for Safety Panelboards
UL 83	(2017; Reprint Mar 2020) UL Standard for Safety Thermoplastic-Insulated Wires and Cables
UL 248-4	(2010; Reprint Apr 2019) Low-Voltage Fuses - Part 4: Class CC Fuses
UL 248-8	(2011; Reprint Aug 2020) Low-Voltage Fuses - Part 8: Class J Fuses

UL 248-10	(2011; Reprint Aug 2020) Low-Voltage Fuses - Part 10: Class L Fuses
UL 248-12	(2011; Reprint Aug 2020) Low Voltage Fuses - Part 12: Class R Fuses
UL 248-15	(2018) Low-Voltage Fuses - Part 15: Class T Fuses
UL 360	(2013; Reprint Jan 2024) UL Standard for Safety Liquid-Tight Flexible Metal Conduit
UL 467	(2022) UL Standard for Safety Grounding and Bonding Equipment
UL 486A-486B	(2018; Reprint Jul 2023) UL Standard for Safety Wire Connectors
UL 486C	(2018; Reprint May 2021) UL Standard for Safety Splicing Wire Connectors
UL 489	(2016; Rev 2019) UL Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
UL 498	(2017; Reprint May 2023) UL Standard for Safety Attachment Plugs and Receptacles
UL 506	(2017; Reprint Jan 2022) UL Standard for Safety Specialty Transformers
UL 508	(2018; Reprint Jul 2021) UL Standard for Safety Industrial Control Equipment
UL 510	(2020; Dec 2022) UL Standard for Safety Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape
UL 514A	(2013; Reprint Jun 2022) UL Standard for Safety Metallic Outlet Boxes
UL 514B	(2012; Reprint Mar 2024) UL Standard for Safety Conduit, Tubing and Cable Fittings
UL 514C	(2014; Reprint Feb 2020) UL Standard for Safety Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers
UL 651	(2011; Reprint May 2022) UL Standard for Safety Schedule 40, 80, Type EB and A Rigid PVC Conduit and Fittings
UL 674	(2022) UL Standard for Safety Electric Motors and Generators for Use in Hazardous (Classified) Locations
UL 719	(2015; Reprint Nov 2023) UL Standard for Safety Nonmetallic-Sheathed Cables

UL 797	(2007; Reprint Apr 2023) UL Standard for Safety Electrical Metallic Tubing -- Steel
UL 817	(2015; Reprint May 2023) UL Standard for Safety Cord Sets and Power-Supply Cords
UL 854	(2020; Reprint Nov 2023) Standard for Service-Entrance Cables
UL 869A	(2006; Reprint Jun 2020) Reference Standard for Service Equipment
UL 943	(2016; Reprint Sep 2023) UL Standard for Safety Ground-Fault Circuit-Interrupters
UL 984	(1996; Reprint Sep 2005) Hermetic Refrigerant Motor-Compressors
UL 1063	(2017; Reprint Jun 2022) UL Standard for Safety Machine-Tool Wires and Cables
UL 1203	(2023; Reprint Oct 2023) UL Standard for Safety Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations
UL 1242	(2006; Reprint Apr 2022) UL Standard for Safety Electrical Intermediate Metal Conduit -- Steel
UL 1449	(2021; Reprint Dec 2022) UL Standard for Safety Surge Protective Devices
UL 1569	(2018) UL Standard for Safety Metal-Clad Cables
UL 1660	(2019; Reprint Jan 2022) Liquid-Tight Flexible Nonmetallic Conduit
UL 2043	(2023) Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces
UL 4248-1	(2022) UL Standard for Safety Fuseholders - Part 1: General Requirements
UL 4248-12	(2018; Reprint Feb 2022) UL Standard for Safety Fuseholders - Part 12: Class R

1.2 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, are as defined in IEEE Stds Dictionary.

1.3 RELATED REQUIREMENTS

Section 25 05 11 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS applies to this section, with the additions and modifications specified herein.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Panelboards; G

Transformers; G
Marking Strips Drawings; G

Receptacles; G

Circuit Breakers; G

Switches; G

Transformers; G

Enclosed Circuit Breakers; G

Motor Controllers; G

CATV Outlets; G

Secondary Bonding Busbar; G

Surge Protective Devices; G

SD-05 Design Data

Cable Trays; G

SD-06 Test Reports

600-volt Wiring Test; G

Grounding System Test; G

Transformer Tests; G

Ground-fault Receptacle Test; G

SD-07 Certificates

Fuses; G

SD-09 Manufacturer's Field Reports

Transformer Factory Tests

1.5 QUALITY ASSURANCE

1.5.1 Fuses

Submit coordination data as specified in paragraph, FUSES of this section.

1.5.2 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "must" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Provide equipment, materials, installation, and workmanship in accordance with NFPA 70 unless more stringent requirements are specified or indicated. NECA NEIS 1 shall be considered the minimum standard for workmanship.

1.5.3 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship and:

- a. Have been in satisfactory commercial or industrial use for 2 years prior to bid opening including applications of equipment and materials under similar circumstances and of similar size.
- b. Have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period.
- c. Where two or more items of the same class of equipment are required, provide products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.5.3.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.5.3.2 Material and Equipment Manufacturing Date

Products manufactured more than 3 years prior to date of delivery to site are not acceptable.

1.6 WARRANTY

Provide equipment items supported by service organizations that are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

As a minimum, meet requirements of UL, where UL standards are established for those items, and requirements of NFPA 70 for all materials, equipment, and devices.

2.2 CONDUIT AND FITTINGS

Conform to the following:

2.2.1 Rigid Metallic Conduit

2.2.1.1 Rigid, Threaded Zinc-Coated Steel Conduit

ANSI C80.1, UL 6.

2.2.1.2 Rigid Aluminum Conduit

ANSI C80.5, UL 6A.

2.2.2 Rigid Nonmetallic Conduit

PVC Type EPC-40 in accordance with NEMA TC 2, UL 651.

2.2.3 Intermediate Metal Conduit (IMC)

UL 1242, zinc-coated steel only.

2.2.4 Electrical, Zinc-Coated Steel Metallic Tubing (EMT)

UL 797, ANSI C80.3.

2.2.5 Plastic-Coated Rigid Steel and IMC Conduit

NEMA RN 1, Type 40(40 mils thick).

2.2.6 Flexible Metal Conduit

UL 1, limited to 6 feet.

2.2.6.1 Liquid-Tight Flexible Metal Conduit, Steel

UL 360, limited to 6 feet.

2.2.7 Fittings for Metal Conduit, EMT, and Flexible Metal Conduit

UL 514B. Ferrous fittings: cadmium- or zinc-coated in accordance with UL 514B.

2.2.7.1 Fittings for Rigid Metal Conduit and IMC

Threaded-type. Split couplings unacceptable.

2.2.7.2 Fittings for EMT

Steel compression type.

2.2.8 Fittings for Rigid Nonmetallic Conduit

NEMA TC 3 for PVC, and UL 514B.

2.2.9 Liquid-Tight Flexible Nonmetallic Conduit

UL 1660.

2.3 CABLE TRAYS

2.3.1 Basket-Type Cable Trays

Provide size as indicated with maximum wire mesh spacing of 2 by 4 inch.

2.3.2 Ladder-Type Cable Trays

Provide size as indicated with maximum rung spacing of 9 inches. Cable tray must be suitable for use as an equipment grounding conductor.

2.4 OPEN TELECOMMUNICATIONS CABLE SUPPORT

2.4.1 Open Top Cable Supports

Provide open top cable supports in accordance with UL 2043. Provide galvanized steel open top cable supports as indicated.

2.4.2 Closed Ring Cable Supports

Provide closed ring cable supports in accordance with UL 2043. Provide galvanized steel closed ring cable supports as indicated.

2.5 OUTLET BOXES AND COVERS

UL 514A, cadmium- or zinc-coated, if ferrous metal. UL 514C, if nonmetallic.

2.5.1 Floor Outlet Boxes

Provide the following:

- a. Boxes: adjustable and concrete tight.
- b. Each outlet: consisting of cast-metal body with threaded openings, or sheet-steel body with knockouts for conduits, adjustable, brass flange ring, and cover plate with 3/4 inch threaded plug.
- c. Telecommunications outlets: consisting of flush, aluminum or stainless steel housing with a receptacle as specified and 3/4 inch top opening.
- d. Receptacle outlets: consisting of flush aluminum or stainless steel housing with duplex-type receptacle as specified herein.
- e. Provide gaskets where necessary to ensure watertight installation.

2.5.2 Outlet Boxes for Telecommunications System

Provide the following:

- a. Standard type 4 inches square by 2 1/8 inches deep.

- b. Outlet boxes for wall-mounted telecommunications outlets: 4 by 2 1/8 by 2 1/8 inches deep.
- c. Depth of boxes: large enough to allow manufacturers' recommended conductor bend radii.
- d. Outlet boxes for fiber optic telecommunication outlets: include a minimum 3/8 inch deep single or two gang plaster ring as shown and installed using a minimum one inch conduit system.
- e. Outlet boxes for handicapped telecommunications station: 4 by 2 1/8 by 2 1/8 inches deep.

2.6 CABINETS, JUNCTION BOXES, AND PULL BOXES

UL 50; volume greater than 100 cubic inches, NEMA Type 1 enclosure; sheet steel, hot-dip, zinc-coated. Where exposed to wet, damp, or corrosive environments, NEMA Type 4X.

2.7 WIRES AND CABLES

Provide wires and cables in accordance applicable requirements of NFPA 70 and UL for type of insulation, jacket, and conductor specified or indicated. Do not use wires and cables manufactured more than 24 months prior to date of delivery to site.

2.7.1 Conductors

Provide the following:

- a. Conductor sizes and capacities shown are based on copper, unless indicated otherwise.
- b. Conductors No. 8 AWG and larger diameter: stranded.
- c. Conductors No. 10 AWG and smaller diameter: solid.
- d. Conductors for remote control, alarm, and signal circuits, classes 1, 2, and 3: stranded unless specifically indicated otherwise.
- e. Conductors indicated to be No. 6 AWG or smaller diameter: copper. Conductors indicated to be No. 4 AWG and larger diameter: either copper or aluminum, unless type of conductor material is specifically indicated, or specified, or required by equipment manufacturer.

2.7.1.1 Equipment Manufacturer Requirements

When manufacturer's equipment requires copper conductors at the terminations or requires copper conductors to be provided between components of equipment, provide copper conductors or splices, splice boxes, and other work required to satisfy manufacturer's requirements.

2.7.1.2 Aluminum Conductors

Provide aluminum conductors of AA-8000 series electrical grade aluminum alloy conductors. Type EC/1350 aluminum is not acceptable. If Contractor chooses to provide aluminum for conductors No. 4 AWG and larger diameter, Contractor is responsible for increasing conductor size to have same ampacity as copper size indicated; increasing conduit and pull box sizes

to accommodate larger size aluminum conductors in accordance with NFPA 70; ensuring that pulling tension rating of aluminum conductor is sufficient; providing panelboards that are UL listed for use with aluminum, and so labeled; relocating equipment, modifying equipment terminations, resizing equipment; and resolving problems that are direct results of providing aluminum conductors in lieu of copper.

2.7.1.3 Minimum Conductor Sizes

Provide minimum conductor size in accordance with the following:

- a. Branch circuits: No. 12 AWG.
- b. Class 1 remote-control and signal circuits: No. 14 AWG.
- c. Class 2 low-energy, remote-control and signal circuits: No. 16 AWG.
- d. Class 3 low-energy, remote-control, alarm and signal circuits: No. 22 AWG.

2.7.2 Color Coding

Provide color coding for service, feeder, branch, control, and signaling circuit conductors.

2.7.2.1 Ground and Neutral Conductors

Provide color coding of ground and neutral conductors as follows:

- a. Grounding conductors: Green.
- b. Neutral conductors: White.
- c. Exception, where neutrals of more than one system are installed in same raceway or box, other neutrals color coding: white with a different colored (not green) stripe for each.

2.7.2.2 Ungrounded Conductors

Provide color coding of ungrounded conductors in different voltage systems as follows:

- a. 208/120 volt, three-phase
 - (1) Phase A - black
 - (2) Phase B - red
 - (3) Phase C - blue
- b. 480/277 volt, three-phase
 - (1) Phase A - brown
 - (2) Phase B - orange
 - (3) Phase C - yellow

- c. 120/240 volt, single phase: Black and red
- d. On three-phase, four-wire delta system, high leg: orange, as required by NFPA 70.

2.7.3 Insulation

Unless specified or indicated otherwise or required by NFPA 70, provide power and lighting wires rated for 600-volts, Type THWN/THHN conforming to UL 83 or Type XHHW conforming to UL 44, except that grounding wire may be type TW conforming to UL 83; remote-control and signal circuits: Type TW or TF, conforming to UL 83. Where equipment or devices require 90-degree Centigrade (C) conductors, provide only conductors with 90-degree C insulation or better.

2.7.4 Bonding Conductors

ASTM B1, solid bare copper wire for sizes No. 8 AWG and smaller diameter; ASTM B8, Class B, stranded bare copper wire for sizes No. 6 AWG and larger diameter.

2.7.4.1 Telecommunications Bonding Backbone (TBB)

Provide a copper conductor TBB in accordance with TIA-607 with No. 6 AWG minimum size, and sized at 2 kcmil per linear foot of conductor length up to a maximum size of 750 kcmil. Provide insulated TBB with insulation as specified in the paragraph INSULATION and meeting the fire ratings of its pathway.

2.7.4.2 Bonding Conductor for Telecommunications

Provide a copper conductor Bonding Conductor for Telecommunications between the telecommunications main grounding busbar (PBB) and the electrical service ground in accordance with TIA-607. Size the bonding conductor for telecommunications the same as the TBB.

2.7.5 Service Entrance Cables

Service Entrance (SE) and Underground Service Entrance (USE) Cables, UL 854.

2.7.6 Nonmetallic Sheathed Cable

UL 719, Type NM or NMC.

2.7.7 Wire and Cable for 400 Hertz (Hz) Circuits

Insulated copper conductors.

2.7.8 Metal-Clad Cable

UL 1569; NFPA 70, Type MC cable.

2.7.9 Armored Cable

UL 4; NFPA 70, Type AC cable.

2.7.10 Mineral-Insulated, Metal-Sheathed Cable

UL listed; NFPA 70, Type MI cable. Do not use sheathing containing asbestos fibers.

2.7.11 Flat Conductor Cable

UL listed; NFPA 70, Type FCC.

2.7.12 Cable Tray Cable or Power Limited Tray Cable

UL listed; type TC or PLTC.

2.7.13 Cord Sets and Power-Supply Cords

UL 817.

2.8 SPLICES AND TERMINATION COMPONENTS

UL 486A-486B for wire connectors and UL 510 for insulating tapes. Connectors for No. 10 AWG and smaller diameter wires: insulated, pressure-type in accordance with UL 486A-486B or UL 486C (twist-on splicing connector). Provide solderless terminal lugs on stranded conductors.

2.9 DEVICE PLATES

Provide the following:

- a. UL listed, one-piece device plates for outlets to suit the devices installed.
- b. For metal outlet boxes, plates on unfinished walls: zinc-coated sheet steel or cast metal having round or beveled edges.
- c. For nonmetallic boxes and fittings, other suitable plates may be provided.
- d. Plates on finished walls: nylon or lexan, minimum 0.03 inch wall thickness and same color as receptacle or toggle switch with which they are mounted.
- f. Screws: machine-type with countersunk heads in color to match finish of plate.
- g. Sectional type device plates are not be permitted.
- h. Plates installed in wet locations: gasketed and UL listed for "wet locations."

2.10 SWITCHES

2.10.1 Toggle Switches

NEMA WD 1, UL 20, single pole, three-way, and four-way, totally enclosed with bodies of thermoplastic or thermoset plastic and mounting strap with grounding screw. Include the following:

- a. Handles: thermoplastic with color as indicated by Interiors plan.

- b. Wiring terminals: screw-type, side-wired.
- c. Contacts: silver-cadmium and contact arm - one-piece copper alloy.
- d. Switches: rated quiet-type ac only, 120/277 volts, with current rating and number of poles indicated.

2.10.2 Breakers Used as Switches

For 120- and 277-Volt fluorescent fixtures, mark breakers "SWD" in accordance with UL 489.

2.10.3 Disconnect Switches

NEMA KS 1. Provide heavy duty-type switches where indicated, where switches are rated higher than 240 volts, and for double-throw switches. Utilize Class R fuseholders and fuses for fused switches, unless indicated otherwise. Provide horsepower rated for switches serving as the motor-disconnect means. Provide switches in NEMA 1, 3R, or 4X Type 304 stainless steel, enclosure as indicated per NEMA ICS 6.

2.11 FUSES

NEMA FU 1. Provide complete set of fuses for each fusible switch. Coordinate time-current characteristics curves of fuses serving motors or connected in series with circuit breakers or other circuit protective devices for proper operation. Submit coordination data for approval. Provide fuses with a voltage rating not less than circuit voltage.

2.11.1 Fuseholders

Provide in accordance with UL 4248-1.

2.11.2 Cartridge Fuses, Current Limiting Type (Class R)

UL 248-12, Class RK-5 time-delay type. Provide only Class R associated fuseholders in accordance with UL 4248-12.

2.11.3 Cartridge Fuses, High-Interrupting Capacity, Current Limiting Type (Classes J, L, and CC)

UL 248-8, UL 248-10, UL 248-4, Class J for zero to 600 amperes, Class L for 601 to 6,000 amperes, and Class CC for zero to 30 amperes.

2.11.4 Cartridge Fuses, Current Limiting Type (Class T)

UL 248-15, Class T for zero to 1,200 amperes, 300 volts; and zero to 800 amperes, 600 volts.

2.12 RECEPTACLES

Provide the following:

- a. UL 498, general purpose specification grade, grounding-type. Residential grade receptacles are not acceptable.
- b. Ratings and configurations: as indicated.
- c. Bodies: as per NEMA WD 1.

- d. Face and body: thermoplastic supported on a metal mounting strap.
- e. Dimensional requirements: per NEMA WD 6.
- f. Screw-type, side-wired wiring terminals or of the solderless pressure type having suitable conductor-release arrangement.
- g. Grounding pole connected to mounting strap.
- h. The receptacle: containing triple-wipe power contacts and double or triple-wipe ground contacts.
- i. Controlled receptacles: as required per ASHRAE 90.1. Provide marking for controlled receptacle per NFPA 70.

2.12.1 Weatherproof Receptacles

Provide receptacles, UL listed for use in "wet locations" with integral GFCI protection. Include cast metal box with gasketed, hinged, lockable and weatherproof while-in-use, polycarbonate, UV resistant/stabilized extra-duty rated hood.

2.12.2 Ground-Fault Circuit Interrupter Receptacles

UL 943, duplex type for mounting in standard outlet box. Provide device capable of detecting current leak when the current to ground is 6 milliamperes or higher, and tripping per requirements of UL 943 for Class A ground-fault circuit interrupter devices. Provide screw-type, side-wired wiring terminals or pre-wired (pigtail) leads.

2.12.3 Special Purpose Receptacles

Provide in ratings indicated.

2.13 PANELBOARDS

Provide panelboards in accordance with the following:

- a. UL 67 and UL 50 having a short-circuit current rating as indicated.
- b. Panelboards for use as service disconnecting means: additionally conform to UL 869A.
- c. Panelboards: circuit breaker-equipped.
- d. Designed such that individual breakers can be removed without disturbing adjacent units or without loosening or removing supplemental insulation supplied as means of obtaining clearances as required by UL.
- e. Use of "Subfeed Breakers" is not acceptable.
- f. Main breaker: "separately" mounted "above" or "below" branch breakers.
- g. Where "space only" is indicated, make provisions for future installation of breakers.

- h. Directories: indicate load served by each circuit in panelboard.
- i. Directories: indicate source of service to panelboard (e.g., Panel PA served from Panel MDP).
- j. Type directories and mount in holder behind transparent protective covering.
- k. Panelboards: listed and labeled for their intended use.
- l. Panelboard nameplates: provided in accordance with paragraph FIELD FABRICATED NAMEPLATES.

2.13.1 Enclosure

Provide panelboard enclosure in accordance with the following:

- a. UL 50.
- b. Cabinets mounted outdoors or flush-mounted: hot-dipped galvanized after fabrication.
- c. Cabinets: painted in accordance with paragraph FIELD APPLIED PAINTING.
- d. Outdoor cabinets: NEMA 4x with a removable steel plate 1/4 inch thick in the bottom for field drilling for conduit connections.
- e. Front edges of cabinets: form-flanged or fitted with structural shapes welded or riveted to the sheet steel, for supporting the panelboard front.
- f. All cabinets: fabricated such that no part of any surface on the finished cabinet deviates from a true plane by more than 1/8 inch.
- g. Holes: provided in the back of indoor surface-mounted cabinets, with outside spacers and inside stiffeners, for mounting the cabinets with a 1/2 inch clear space between the back of the cabinet and the wall surface.
- h. Flush doors: mounted on hinges that expose only the hinge roll to view when the door is closed.
- i. Each door: fitted with a combined catch and lock latch.
- j. Keys: two provided with each lock, with all locks keyed alike.
- k. Finished-head cap screws: provided for mounting the panelboard fronts on the cabinets.

2.13.2 Panelboard Buses

Support bus bars on bases independent of circuit breakers. Design main buses and back pans so that breakers may be changed without machining, drilling, or tapping. Provide isolated neutral bus in each panel for connection of circuit neutral conductors. Provide separate ground bus identified as equipment grounding bus per UL 67 for connecting grounding conductors; bond to steel cabinet.

2.13.2.1 Panelboard Neutrals for Non-Linear Loads

Provide in accordance with the following:.

- a. UL listed, with panelboard type specifically UL heat rise tested for use on non-linear loads.
- b. Panelboard: heat rise tested in accordance with UL 67, except with the neutral assembly installed and carrying 200 percent of the phase bus current during testing.
- c. Verification of the testing procedure: provided upon request.
- d. Two neutral assemblies paralleled together with cable is not acceptable.
- e. Nameplates for panelboard rated for use on non-linear loads: marked "SUITABLE FOR NON-LINEAR LOADS" and in accordance with paragraph FIELD FABRICATED NAMEPLATES.
- f. Provide a neutral label with instructions for wiring the neutral of panelboards rated for use on non-linear loads.

2.13.3 Circuit Breakers

UL 489, thermal magnetic-type having a minimum short-circuit current rating equal to the short-circuit current rating of the panelboard in which the circuit breaker will be mounted. Breaker terminals: UL listed as suitable for type of conductor provided. Series rated circuit breakers and plug-in circuit breakers are unacceptable.

2.13.3.1 Multipole Breakers

Provide common trip-type with single operating handle. Design breaker such that overload in one pole automatically causes all poles to open. Maintain phase sequence throughout each panel so that any three adjacent breaker poles are connected to Phases A, B, and C, respectively.

2.13.3.2 Circuit Breaker With Ground-Fault Circuit Interrupter

UL 943 and NFPA 70. Provide with auto-monitoring (self-test) and lockout features, "push-to-test" button, visible indication of tripped condition, and ability to detect and trip when current imbalance is 6 milliamperes or higher per requirements of UL 943 for Class A ground-fault circuit interrupter devices.

2.13.4 400 Hz Panelboard and Breakers

Provide panelboards and breakers for use on 400 Hz systems rated and labeled "400 Hz."

2.13.5 Lighting Control Panelboards

Provided a lighting control panelboard having the following features:

- a. Minimum sixteen schedules including a 7-day repeating schedule with sixteen daily on/off periods.
- b. Minimum sixteen lighting zones grouping branch breakers that are

controlled by schedules, manual inputs, or override commands.

- c. Electronic clock including real-time, astronomical clock, and leap year and daylight savings time adjustments.
- d. Burn-hour tracking.
- e. Remote circuit breaker operation.

2.14 ENCLOSED CIRCUIT BREAKERS

UL 489. Individual molded case circuit breakers with voltage and continuous current ratings, number of poles, overload trip setting, and short circuit current interrupting rating as indicated. Enclosure type as indicated. Provide solid neutral.

2.15 TRANSFORMERS

Provide transformers in accordance with the following:

- a. NEMA ST 20, general purpose, dry-type, self-cooled, ventilated.
- b. Provide transformers in NEMA 1 enclosure.
- c. Taps for transformers 15 kVA and larger: Two 2.5 percent taps Full Capacity Above Nominal (FCAN) and four 2.5 percent taps Full Capacity Below Nominal (FCBN).
- d. Transformer insulation system:
 - (1) 220 degrees C insulation system for transformers 15 kVA and greater, with temperature rise not exceeding 115 degrees C under full-rated load in maximum ambient of 40 degrees C.
 - (2) 180 degrees C insulation for transformers rated 10 kVA and less, with temperature rise not exceeding 80 degrees C under full-rated load in maximum ambient of 40 degrees C.
- f. Transformer of 115 degrees C temperature rise: capable of carrying continuously 115 percent of nameplate kVA without exceeding insulation rating.

2.15.1 Specified Transformer Efficiency

Transformers, indicated and specified with: 480V primary, 80 degrees C or 115 degrees C temperature rise, kVA ratings of 37.5 to 100 for single phase or 30 to 500 for three phase, energy efficient type. The transformer is not acceptable if the calculated transformer efficiency is less than the efficiency indicated in 10 CFR 431, Subpart K.

2.16 MOTORS

Provide motors in accordance with the following:

- a. NEMA MG 1 except provide fire pump motors as specified in Section 21 30 00 FIRE PUMPS.

- b. Hermetic-type sealed motor compressors: Also comply with UL 984.
- c. Provide the size in terms of HP, or kVA, or full-load current, or a combination of these characteristics, and other characteristics, of each motor as indicated or specified.
- d. Determine specific motor characteristics to ensure provision of correctly sized starters and overload heaters.
- e. Rate motors for operation on 208-volt, 3-phase circuits with a terminal voltage rating of 200 volts, and those for operation on 480-volt, 3-phase circuits with a terminal voltage rating of 460 volts.
- f. Use motors designed to operate at full capacity with voltage variation of plus or minus 10 percent of motor voltage rating.
- g. Unless otherwise indicated, use continuous duty type motors if rated 1 HP and above.
- h. Where fuse protection is specifically recommended by the equipment manufacturer, provide fused switches in lieu of non-fused switches indicated.

2.16.1 High Efficiency Single-Phase Motors

Single-phase fractional-horsepower alternating-current motors: high efficiency types are not acceptable. In exception, for special purpose motors and motor-driven equipment with a minimum seasonal or overall efficiency rating, such as a SEER rating, provide equipment with motor to meet the overall system rating indicated.

2.16.2 Motor Sizes

Provide size for duty to be performed, not exceeding the full-load nameplate current rating when driven equipment is operated at specified capacity under most severe conditions likely to be encountered. When motor size provided differs from size indicated or specified, make adjustments to wiring, disconnect devices, and branch circuit protection to accommodate equipment actually provided. Provide controllers for motors rated 1-hp and above with electronic phase-voltage monitors designed to protect motors from phase-loss, undervoltage, and overvoltage. Provide protection for motors from immediate restart by a time adjustable restart relay.

2.16.3 Wiring and Conduit

Provide internal wiring for components of packaged equipment as an integral part of the equipment. Provide power wiring and conduit for field-installed equipment using adjustable speed drive (ASD) manufacturer required wiring type and length, and motor control equipment forming part of motor control centers or switchgear assemblies, the conduit and wiring connecting such centers, assemblies, or other power sources to equipment as specified herein. Power wiring and conduit: conform to the requirements specified herein. Control wiring: provided under, and conform to, the requirements of the section specifying the associated

equipment.

2.17 MOTOR CONTROLLERS

Provide motor controllers in accordance with the following:

- a. UL 508, NEMA ICS 1, and NEMA ICS 2, except fire pump controllers as specified in Section 21 30 00 FIRE PUMPS.
- b. Provide controllers with thermal overload protection in each phase, and one spare normally open auxiliary contact, and one spare normally closed auxiliary contact.
- c. Provide controllers for motors rated 1-hp 746 watts and above with electronic phase-voltage monitors designed to protect motors from phase-loss, undervoltage, and overvoltage.
- d. Provide protection for motors from immediate restart by a time adjustable restart relay.
- e. When used with pressure, float, or similar automatic-type or maintained-contact switch, provide a hand/off/automatic selector switch with the controller.
- f. Connections to selector switch: wired such that only normal automatic regulatory control devices are bypassed when switch is in "hand" position.
- g. Safety control devices, such as low and high pressure cutouts, high temperature cutouts, and motor overload protective devices: connected in motor control circuit in "hand" and "automatic" positions.
- h. Control circuit connections to hand/off/automatic selector switch or to more than one automatic regulatory control device: made in accordance with indicated or manufacturer's approved wiring diagram.
- i. Provide selector switch with the means for locking in any position.
- j. Provide a disconnecting means, capable of being locked in the open position, for the motor that is located in sight from the motor location and the driven machinery location. As an alternative, provide a motor controller disconnect, capable of being locked in the open position, to serve as the disconnecting means for the motor if it is in sight from the motor location and the driven machinery location.
- k. Overload protective devices: provide adequate protection to motor windings; be thermal inverse-time-limit type; and include manual reset-type pushbutton on outside of motor controller case.
- l. Cover of combination motor controller and manual switch or circuit breaker: interlocked with operating handle of switch or circuit breaker so that cover cannot be opened unless handle of switch or circuit breaker is in "off" position.
- m. Provide controllers in hazardous locations with classifications as indicated.

2.17.1 Control Wiring

Provide control wiring in accordance with the following:

- a. All control wire: stranded tinned copper switchboard wire with 600-volt flame-retardant insulation Type SIS meeting UL 44, or Type MTW meeting UL 1063, and passing the VW-1 flame tests included in those standards.
- b. Hinge wire: Class K stranding.
- c. Current transformer secondary leads: not smaller than No. 10 AWG.
- d. Control wire minimum size: No. 14 AWG.
- e. Power wiring for 480-volt circuits and below: the same type as control wiring with No. 12 AWG minimum size.
- f. Provide wiring and terminal arrangement on the terminal blocks to permit the individual conductors of each external cable to be terminated on adjacent terminal points.

2.17.2 Control Circuit Terminal Blocks

Provide control circuit terminal blocks in accordance with the following:

- a. NEMA ICS 4.
- b. Control circuit terminal blocks for control wiring: molded or fabricated type with barriers, rated not less than 600 volts.
- c. Provide terminals with removable binding, fillister or washer head screw type, or of the stud type with contact and locking nuts.
- d. Terminals: not less than No. 10 in size with sufficient length and space for connecting at least two indented terminals for 10 AWG conductors to each terminal.
- e. Terminal arrangement: subject to the approval of the Contracting Officer with not less than four spare terminals or 10 percent, whichever is greater, provided on each block or group of blocks.
- f. Modular, pull apart, terminal blocks are acceptable provided they are of the channel or rail-mounted type.
- g. Submit data showing that any proposed alternate will accommodate the specified number of wires, are of adequate current-carrying capacity, and are constructed to assure positive contact between current-carrying parts.

2.17.2.1 Types of Terminal Blocks

- a. Short-Circuiting Type: Short-circuiting type terminal blocks: furnished for all current transformer secondary leads with provision for shorting together all leads from each current transformer without first opening any circuit. Terminal blocks: comply with the requirements of paragraph CONTROL CIRCUIT TERMINAL BLOCKS above.
- b. Load Type: Load terminal blocks rated not less than 600 volts and of

adequate capacity: provided for the conductors for NEMA Size 3 and smaller motor controllers and for other power circuits, except those for feeder tap units. Provide terminals of either the stud type with contact nuts and locking nuts or of the removable screw type, having length and space for at least two indented terminals of the size required on the conductors to be terminated. For conductors rated more than 50 amperes, provide screws with hexagonal heads. Conducting parts between connected terminals must have adequate contact surface and cross-section to operate without overheating. Provide each connected terminal with the circuit designation or wire number placed on or near the terminal in permanent contrasting color.

2.17.3 Control Circuits

Control circuits: maximum voltage of 120 volts derived from control transformer in same enclosure. Transformers: conform to UL 506, as applicable. Transformers, other than transformers in bridge circuits: provide primaries wound for voltage available and secondaries wound for correct control circuit voltage. Size transformers so that 80 percent of rated capacity equals connected load. Provide disconnect switch on primary side. Provide one fused secondary lead with the other lead grounded.

2.17.4 Enclosures for Motor Controllers

NEMA ICS 6.

2.17.5 Multiple-Speed Motor Controllers and Reversible Motor Controllers

Across-the-line-type, electrically and mechanically interlocked. Multiple-speed controllers: include compelling relays and multiple-button, station-type with pilot lights for each speed.

2.17.6 Pushbutton Stations

Provide with "start/stop" momentary contacts having one normally open and one normally closed set of contacts, and red lights to indicate when motor is running. Stations: heavy duty, oil-tight design.

2.17.7 Pilot and Indicating Lights

Provide LED cluster lamps.

2.18 MANUAL MOTOR STARTERS (MOTOR RATED SWITCHES)

Singleor Three pole designed for surface mounting with overload protection.

2.19 LOCKOUT REQUIREMENTS

Provide circuit breakers, disconnecting means, and other devices that are electrical energy-isolating capable of being locked out for machines and other equipment to prevent unexpected startup or release of stored energy in accordance with 29 CFR 1910.147, NFPA 70E and 29 CFR 1910.303. Comply with requirements of Division 23, "Heating, Ventilating, and Air Conditioning (HVAC)" for mechanical isolation of machines and other equipment.

2.20 TELECOMMUNICATIONS SYSTEM

Provide system of telecommunications wire-supporting structures (pathway), including: outlet boxes, conduits with pull wires, cable trays, and other accessories for telecommunications outlets and pathway in accordance with TIA-569 and as specified herein. Additional telecommunications requirements are specified in Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM.

2.21 COMMUNITY ANTENNA TELEVISION (CATV) SYSTEM

Additional CATV requirements are specified in Section 27 05 13.43 TELEVISION DISTRIBUTION SYSTEM.

2.21.1 CATV Outlets

Provide flush mounted, 75-ohm, F-type connector outlet rated from 5 to 1000 MHz in standard electrical outlet boxes with isolation barrier with mounting frame.

2.21.2 CATV Faceplates

Provide modular faceplates for mounting of CATV Outlets. Faceplate: include designation labels and label covers for circuit identification. Faceplate color: match outlet and switch coverplates.

2.21.3 Backboards

Coordinate CATV backboard requirements with telecommunications backboard requirements as specified in Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING.

2.22 GROUNDING AND BONDING EQUIPMENT

2.22.1 Ground Rods

UL 467. Ground rods: cone pointed copper-clad steel, with minimum diameter of 3/4 inch and minimum length 10 feet. Sectional type rods may be used for rods 20 feet or longer.

2.22.2 Ground Bus

Copper ground bus: provided in the electrical equipment rooms as indicated.

2.22.3 Secondary Bonding Busbar

Provide corrosion-resistant grounding busbar suitable for indoor installation in accordance with TIA-607. Busbars: plated for reduced contact resistance. If not plated, clean the busbar prior to fastening the conductors to the busbar and apply an anti-oxidant to the contact area to control corrosion and reduce contact resistance. Provide a Primary bonding busbar (PBB) in the telecommunications entrance facility. The Primary bonding busbar (PBB): sized in accordance with the immediate application requirements and with consideration of future growth. Provide Secondary bonding busbars with the following:

- a. Predrilled copper busbar provided with holes for use with standard sized lugs,

- b. Minimum dimensions of 0.25 in thick by 4 in wide for the PBB with length as indicated;
- c. Listed by a nationally recognized testing laboratory.

2.23 HAZARDOUS LOCATIONS

Electrical materials, equipment, and devices for installation in hazardous locations, as defined by NFPA 70: specifically approved by Underwriters' Laboratories, Inc., or Factory Mutual for particular "Class," "Division," and "Group" of hazardous locations involved. Boundaries and classifications of hazardous locations: as indicated. Equipment in hazardous locations: comply with UL 1203 for electrical equipment and industrial controls and UL 674 for motors.

2.24 MANUFACTURER'S NAMEPLATE

Provide on each item of equipment a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

2.25 FIELD FABRICATED NAMEPLATES

Provide field fabricated nameplates in accordance with the following:

- a. ASTM D709.
- b. Provide laminated plastic nameplates for each equipment enclosure, relay, switch, and device; as specified or as indicated on the drawings.
- c. Each nameplate inscription: identify the function and, when applicable, the position.
- d. Nameplates: melamine plastic, 0.125 inch thick, white with black center core.
- e. Surface: matte finish. Corners: square. Accurately align lettering and engrave into the core.
- f. Minimum size of nameplates: one by 2.5 inches.
- g. Lettering size and style: a minimum of 0.25 inch high normal block style.

2.26 WARNING SIGNS

Provide warning signs for flash protection in accordance with NFPA 70E and NEMA Z535.4 for switchboards, panelboards, industrial control panels, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized. Provide field installed signs to warn qualified persons of potential electric arc flash hazards when warning signs are not provided by the manufacturer. Provide marking that is clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

2.27 FIRESTOPPING MATERIALS

Provide firestopping around electrical penetrations in accordance with Section 07 84 00 FIRESTOPPING.

2.28 SURGE PROTECTIVE DEVICES

Provide parallel type surge protective devices (SPD) which comply with UL 1449 at the service entrance and panelboards. Provide surge protectors in a NEMA 1 enclosure per NEMA ICS 6. Do not install SPD inside a panelboard or switchboard enclosure. However, SPD may be installed in a separate compartment of a switchgear provided that it is supplied by a dedicated circuit breaker. SPD must have the same short-circuit current rating as the protected equipment and must not be installed at a point of system where the available fault current is in excess of that rating. Use Type 1 or Type 2 SPD and connect on the load side of a dedicated circuit breaker. Submit performance and characteristic curves.

Provide the following modes of protection:

FOR SINGLE PHASE AND THREE PHASE WYE CONNECTED SYSTEMS-

- Phase to phase (L-L)
- Each phase to neutral (L-N)

- Phase to ground (L-G)

SPDs at the service entrance: provide with a minimum surge current rating of 80,000 amperes for L-L mode minimum and 40,000 amperes for other modes (L-N, L-G, and N-G) and downstream SPDs rated 40,000 amperes for L-L mode minimum and 20,000 amperes for other modes (L-N, L-G, and N-G).

Provide SPDs per NFPA 780 for the lightning protection system.

Maximum L-N, and N-G Voltage Protection Rating:

- 700V for 208Y/120V, three phase system
- 1,200V for 480Y/277V, three phase system

Maximum L-G Protection Rating:

- 700V for 208Y/120V, three phase system
- 1,200V for 480Y/277V, three phase system

Maximum L-L Voltage Protection Rating:

- 1,200V for 208Y/120V, three phase system
- 1,800V for 480Y/277V, three phase system

Provide SPDs.

Maximum L-N, L-G, and N-G Voltage Protection Rating:

- 700V for 208Y/120V, three phase system
- 1,200V for 480Y/277V, three phase system

Maximum L-L Voltage Protection Rating:

1,200V for 208Y/120V, three phase system
1,800V for 480Y/277V, three phase system

The minimum MCOV (Maximum Continuous Operating Voltage) rating for L-N and L-G modes of operation: 120 percent of nominal voltage for 240 volts and below; 115 percent of nominal voltage above 240 volts to 480 volts.

2.29 FACTORY APPLIED FINISH

Provide factory-applied finish on electrical equipment in accordance with the following:

- a. NEMA 250 corrosion-resistance test and the additional requirements as specified herein.
- b. Interior and exterior steel surfaces of equipment enclosures: thoroughly cleaned followed by a rust-inhibitive phosphatizing or equivalent treatment prior to painting.
- c. Exterior surfaces: free from holes, seams, dents, weld marks, loose scale or other imperfections.
- d. Interior surfaces: receive not less than one coat of corrosion-resisting paint in accordance with the manufacturer's standard practice.
- e. Exterior surfaces: primed, filled where necessary, and given not less than two coats baked enamel with semigloss finish.
- f. Equipment located indoors: ANSI Light Gray, and equipment located outdoors: ANSI Light Gray.
- g. Provide manufacturer's coatings for touch-up work and as specified in paragraph FIELD APPLIED PAINTING.

2.30 SOURCE QUALITY CONTROL

2.30.1 Transformer Factory Tests

Submittal: include routine NEMA ST 20 transformer test results on each transformer and also provide the results of NEMA "design" and "prototype" tests that were made on transformers electrically and mechanically equal to those specified.

2.31 COORDINATED POWER SYSTEM PROTECTION

Prepare analyses as specified in Section 26 05 73 POWER SYSTEM STUDIES.

PART 3 EXECUTION

3.1 INSTALLATION

Electrical installations, including weatherproof and hazardous locations and ducts, plenums and other air-handling spaces: conform to requirements of NFPA 70 and to requirements specified herein.

3.1.1 Underground Service

Underground service conductors and associated conduit: continuous from service entrance equipment to outdoor power system connection.

3.1.2 Hazardous Locations

Perform work in hazardous locations, as defined by NFPA 70, in strict accordance with NFPA 70 for particular "Class," "Division," and "Group" of hazardous locations involved. Provide conduit and cable seals where required by NFPA 70. Provide conduit with tapered threads.

3.1.3 Service Entrance Identification

Service entrance disconnect devices, switches, and enclosures: labeled and identified as such.

3.1.3.1 Labels

Wherever work results in service entrance disconnect devices in more than one enclosure, as permitted by NFPA 70, label each enclosure, new and existing, as one of several enclosures containing service entrance disconnect devices. Label, at minimum: indicate number of service disconnect devices housed by enclosure and indicate total number of enclosures that contain service disconnect devices. Provide laminated plastic labels conforming to paragraph FIELD FABRICATED NAMEPLATES. Use lettering of at least 0.25 inch in height, and engrave on black-on-white matte finish. Service entrance disconnect devices in more than one enclosure: provided only as permitted by NFPA 70.

3.1.4 Wiring Methods

Provide insulated conductors installed in rigid steel conduit, IMC, rigid nonmetallic conduit, or EMT, except where specifically indicated or specified otherwise or required by NFPA 70 to be installed otherwise. Grounding conductor: separate from electrical system neutral conductor. Provide insulated green equipment grounding conductor for circuit(s) installed in conduit and raceways. Shared neutral, or multi-wire branch circuits, are not permitted with arc-fault circuit interrupters. Minimum conduit size: 1/2 inch in diameter for low voltage lighting and power circuits. Vertical distribution in multiple story buildings: made with metal conduit in fire-rated shafts, with metal conduit extending through shafts for minimum distance of 6 inches. Firestop conduit which penetrates fire-rated walls, fire-rated partitions, or fire-rated floors in accordance with Section 07 84 00 FIRESTOPPING.

3.1.4.1 Pull Wire

Install pull wires in empty conduits. Pull wire: plastic having minimum 200-pound force tensile strength. Leave minimum 36 inches of slack at each end of pull wire.

3.1.4.2 Metal-Clad Cable

Install in accordance with NFPA 70, Type MC cable.

3.1.5 Conduit Installation

Unless indicated otherwise, conceal conduit under floor slabs and within

finished walls, ceilings, and floors. Keep conduit minimum 6 inches away from parallel runs of flues and steam or hot water pipes. Install conduit parallel with or at right angles to ceilings, walls, and structural members where located above accessible ceilings and where conduit will be visible after completion of project.

3.1.5.1 Restrictions Applicable to Aluminum Conduit

- a. Do not install underground or encase in concrete or masonry.
- b. Do not use brass or bronze fittings.
- c. Do not use when the enclosed conductors must be shielded from the effects of High-altitude Electromagnetic Pulse (HEMP).

3.1.5.2 Restrictions Applicable to EMT

- a. Do not install underground.
- b. Do not encase in concrete, mortar, grout, or other cementitious materials.
- c. Do not use in areas subject to physical damage including but not limited to equipment rooms where moving or replacing equipment could physically damage the EMT.
- d. Do not use in hazardous areas.
- e. Do not use outdoors.
- f. Do not use in fire pump rooms.
- g. Do not use when the enclosed conductors must be shielded from the effects of High-altitude Electromagnetic Pulse (HEMP).

3.1.5.3 Restrictions Applicable to Nonmetallic Conduit

- a. PVC Schedule 40.
 - (1) Do not use where subject to physical damage, including but not limited to, mechanical equipment rooms, electrical equipment rooms, fire pump rooms, and where restrictions are applying to both PVC Schedule 40 and PVC Schedule 80.
 - (2) Do not use above grade, except where allowed in this section for rising through floor slab or indicated otherwise.
- b. PVC Schedule 80.
 - (1) Do not use where subject to physical damage, including but not limited to, hospitals, power plant, missile magazines, and other such areas.
 - (2) Do not use in hazardous (classified) areas.
 - (3) Do not use in penetrating fire-rated walls or partitions, or fire-rated floors.

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3.1.5.4 Restrictions Applicable to Flexible Conduit

Use only as specified in paragraph FLEXIBLE CONNECTIONS. Do not use when the enclosed conductors must be shielded from the effects of High-altitude Electromagnetic Pulse (HEMP).

3.1.5.5 Underground Conduit

Plastic-coated rigid steel; plastic-coated steel IMC; PVC, Type EPC-40
Plastic coating: extend minimum 6 inches above floor.

3.1.5.6 Conduit Interior to Buildings for 400 Hz Circuits

Aluminum or nonmetallic. Where 400-Hz circuit runs underground or through concrete, provide PVC Schedule 40 conduit.

3.1.5.7 Conduit for Circuits Rated Greater Than 600 Volts

Rigid metal conduit or IMC only.

3.1.5.8 Conduit Installed Under Floor Slabs

Conduit run under floor slab: located a minimum of 12 inches below the vapor barrier. Seal around conduits at penetrations thru vapor barrier. Use NECA NEIS 1 Table 2a (Minimum Raceway Spacing) to determine under floor slab conduit spacing unless greater spacing is required elsewhere in this section.

3.1.5.9 Conduit Through Floor Slabs

Where conduits rise through floor slabs, do not allow curved portion of bends to be visible above finished slab. Where conduit rises through slab-on grade, seal all electrical penetrations to address radon mitigation and prevent infiltration of air, insects, and vermin.

3.1.5.10 Stub-Ups

Provide conduits stubbed up through concrete floor for connection to free-standing equipment with adjustable top or coupling threaded inside for plugs, set flush with finished floor. Extend conductors to equipment in rigid steel conduit, except that flexible metal conduit may be used 6 inches above floor. Where no equipment connections are made, install screwdriver-operated threaded flush plugs in conduit end.

3.1.5.11 Conduit Support

Support conduit by pipe straps, wall brackets, threaded rod conduit hangers, or ceiling trapeze. Plastic cable ties are not acceptable. Fasten by wood screws to wood; by toggle bolts on hollow masonry units; by concrete inserts or expansion bolts on concrete or brick; and by machine screws, welded threaded studs, or spring-tension clamps on steel work. Threaded C-clamps may be used on rigid steel conduit only. Do not weld conduits or pipe straps to steel structures. Do not exceed one-fourth proof test load for load applied to fasteners. Provide vibration resistant and shock-resistant fasteners attached to concrete ceiling. Do not cut main reinforcing bars for any holes cut to depth of more than 1 1/2 inches in reinforced concrete beams or to depth of more than 3/4 inch in concrete joints. Fill unused holes. In partitions of light steel construction, use sheet metal screws. In suspended-ceiling construction,

run conduit above ceiling. Do not support conduit by ceiling support system. Conduit and box systems: supported independently of both (a) tie wires supporting ceiling grid system, and (b) ceiling grid system into which ceiling panels are placed. Do not share supporting means between electrical raceways and mechanical piping or ducts. Identify independent conduit support in both fire and non-fire rated assemblies per NFPA 70. Coordinate installation with above-ceiling mechanical systems to assure maximum accessibility to all systems. Spring-steel fasteners may be used for lighting branch circuit conduit supports in suspended ceilings in dry locations. Where conduit crosses building expansion joints, provide suitable watertight expansion fitting that maintains conduit electrical continuity by bonding jumpers or other means. For conduits greater than 2 1/2 inches inside diameter, provide supports to resist forces of 0.5 times the equipment weight in any direction and 1.5 times the equipment weight in the downward direction.

3.1.5.12 Directional Changes in Conduit Runs

Make changes in direction of runs with symmetrical bends or cast-metal fittings. Make field-made bends and offsets with hickey or conduit-bending machine. Do not install crushed or deformed conduits. Avoid trapped conduits. Prevent plaster, dirt, or trash from lodging in conduits, boxes, fittings, and equipment during construction. Free clogged conduits of obstructions.

3.1.5.13 Locknuts and Bushings

Fasten conduits to sheet metal boxes and cabinets with two locknuts where required by NFPA 70, where insulated bushings are used, and where bushings cannot be brought into firm contact with the box; otherwise, use at least minimum single locknut and bushing. Provide locknuts with sharp edges for digging into wall of metal enclosures. Install bushings on ends of conduits, and provide insulating type where required by NFPA 70.

3.1.5.14 Flexible Connections

Provide flexible steel conduit between 3 and 6 feet in length for recessed and semirecessed lighting fixtures; for equipment subject to vibration, noise transmission, or movement; and for motors. Install flexible conduit to allow 20 percent slack. Minimum flexible steel conduit size: 1/2 inch diameter. Provide liquid tight flexible nonmetallic conduit in wet and damp locations and in fire pump rooms for equipment subject to vibration, noise transmission, movement or motors. Provide separate ground conductor across flexible connections. Plastic cable ties are not acceptable as a support method.

3.1.5.15 Telecommunications and Signal System Pathway

Install telecommunications pathway in accordance with TIA-569.

- a. Horizontal Pathway: Telecommunications pathways from the work area to the telecommunications room: installed and cabling length requirements in accordance with TIA-568.1. Size conduits in accordance with TIA-569 and as indicated.
- b. Backbone Pathway: Telecommunication pathways from the telecommunications entrance facility to telecommunications rooms, and, telecommunications equipment rooms (backbone cabling): installed in accordance with TIA-569. Size conduits for telecommunications risers

in accordance with TIA-569 and as indicated.

3.1.5.16 Community Antenna Television (CATV) System Conduits

Install a system of CATV wire-supporting structures (pathway), including: outlet boxes, conduits with pull wires and other accessories for CATV outlets and pathway in accordance with TIA-569..

3.1.6 Telecommunications Cable Support Installation

Install open top and closed ring cable supports on 4 ft to 5 ft centers to adequately support and distribute the cable's weight. Use these types of supports to support a maximum of 50 0.25 in diameter cables. Install suspended cables with at least 3 in of clear vertical space above the ceiling tiles and support channels (T-bars). Open top and closed ring cable supports: suspended from or attached to the structural ceiling or walls with hardware or other installation aids specifically designed to support their weight.

3.1.7 Boxes, Outlets, and Supports

Provide boxes in wiring and raceway systems wherever required for pulling of wires, making connections, and mounting of devices or fixtures. Boxes for metallic raceways: cast-metal, hub-type when located in wet locations, when surface mounted on outside of exterior surfaces, when surface mounted on interior walls exposed up to 7 feet above floors and walkways, or when installed in hazardous areas and when specifically indicated. Boxes in other locations: sheet steel, except that aluminum boxes may be used with aluminum conduit, and nonmetallic boxes may be used with nonmetallic conduit system. Provide each box with volume required by NFPA 70 for number of conductors enclosed in box. Boxes for mounting lighting fixtures: minimum 4 inches square, or octagonal, except that smaller boxes may be installed as required by fixture configurations, as approved. Boxes for use in masonry-block or tile walls: square-cornered, tile-type, or standard boxes having square-cornered, tile-type covers. Provide gaskets for cast-metal boxes installed in wet locations and boxes installed flush with outside of exterior surfaces. Provide separate boxes for flush or recessed fixtures when required by fixture terminal operating temperature; provide readily removable fixtures for access to boxes unless ceiling access panels are provided. Support boxes and pendants for surface-mounted fixtures on suspended ceilings independently of ceiling supports. Fasten boxes and supports with wood screws on wood, with bolts and expansion shields on concrete or brick, with toggle bolts on hollow masonry units, and with machine screws or welded studs on steel. In open overhead spaces, cast boxes threaded to raceways need not be separately supported except where used for fixture support; support sheet metal boxes directly from building structure or by bar hangers. Where bar hangers are used, attach bar to raceways on opposite sides of box, and support raceway with approved-type fastener maximum 24 inches from box. When penetrating reinforced concrete members, avoid cutting reinforcing steel.

3.1.7.1 Boxes

Boxes for use with raceway systems: minimum 1 1/2 inches deep, except where shallower boxes required by structural conditions are approved. Boxes for other than lighting fixture outlets: minimum 4 inches square, except that 4 by 2 inch boxes may be used where only one raceway enters outlet.

3.1.7.1.1 Wall-Mounted Telecommunications Outlet Box

Provide double gang electrical boxes, minimum standard size 4-11/16 inches square and 2-1/8 inches deep with plaster ring for connection of single gang faceplate. Design outlet box for recess mounting with the faceplate flush with the wall surface, at the same height as the electrical outlets.

3.1.7.2 Pull Boxes

Construct of at least minimum size required by NFPA 70 of code-gauge aluminum or galvanized sheet steel, except where cast-metal boxes are required in locations specified herein. Provide boxes with screw-fastened covers. Where several feeders pass through common pull box, tag feeders to indicate clearly electrical characteristics, circuit number, and panel designation.

3.1.7.3 Extension Rings

Extension rings are not permitted for new construction.

3.1.8 Mounting Heights

Mount panelboards, circuit breakers and disconnecting switches so height of center of grip of the operating handle of the switch or circuit breaker at its highest position is maximum 79 inches above floor or working platform or as allowed in Section 404.8 per NFPA 70. Mount lighting switches 48 inches above finished floor. Mount receptacles 18 inches above finished floor, unless otherwise indicated. Wall-mounted telecommunications outlets: mounted at height indicated. Mount other devices as indicated. Measure mounting heights of wiring devices and outlets in non-hazardous areas to bottom of device or outlet. Measure mounting heights of receptacle outlet boxes in the hazardous area to the bottom of the outlet box.

3.1.9 Conductor Identification

Provide conductor identification within each enclosure where tap, splice, or termination is made. For conductors No. 6 AWG and smaller diameter, provide color coding by factory-applied, color-impregnated insulation. For conductors No. 4 AWG and larger diameter, provide color coding by plastic-coated, self-sticking markers; colored nylon cable ties and plates; or heat shrink-type sleeves. Identify control circuit terminations in accordance with Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC. Provide telecommunications system conductor identification as specified in Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEMS.

3.1.9.1 Marking Strips

Provide marking strips for identification of power distribution, control, data, and communications cables in accordance with the following:

- a. Provide white or other light-colored plastic marking strips, fastened by screws to each terminal block, for wire designations.
- b. Use permanent ink for the wire numbers
- c. Provide reversible marking strips to permit marking both sides, or provide two marking strips with each block.

- d. Size marking strips to accommodate the two sets of wire numbers.
- e. Assign a device designation in accordance with NEMA ICS 1 to each device to which a connection is made. Mark each device terminal to which a connection is made with a distinct terminal marking corresponding to the wire designation used on the Contractor's schematic and connection diagrams.
- f. The wire (terminal point) designations used on the Contractor's wiring diagrams and printed on terminal block marking strips may be according to the Contractor's standard practice; however, provide additional wire and cable designations for identification of remote (external) circuits for the Government's wire designations.
- g. Prints of the marking strips drawings submitted for approval will be so marked and returned to the Contractor for addition of the designations to the terminal strips and tracings, along with any rearrangement of points required.

3.1.10 Splices

Make splices in accessible locations. Make splices in conductors No. 10 AWG and smaller diameter with insulated, pressure-type connector. Make splices in conductors No. 8 AWG and larger diameter with solderless connector, and cover with insulation material equivalent to conductor insulation.

3.1.10.1 Splices of Aluminum Conductors

Make with solderless circumferential compression-type, aluminum-bodied connectors UL listed for AL/CU. Remove surface oxides from aluminum conductors by wire brushing and immediately apply oxide-inhibiting joint compound and insert in connector. After joint is made, wipe away excess joint compound, and insulate splice.

3.1.11 Terminating Aluminum Conductors

3.1.11.1 Termination to Copper Bus

Terminate aluminum conductors to copper bus either by: (a) inline splicing a copper pigtail, of ampacity at least that of aluminum conductor, or (b) utilizing circumferential, compression-type, aluminum-bodied terminal lug UL listed for AL/CU, and steel Belleville cadmium-plated hardened steel spring washers, flat washers, bolts, and nuts. Carefully install Belleville spring washers with crown up toward nut or bolt head, with concave side of Belleville bearing on heavy-duty, wide series flat washer of larger diameter than Belleville. Tighten nuts sufficiently to flatten Belleville, and leave in position. Lubricate hardware with joint compound prior to making connection. Wire brush and apply joint compound to conductor prior to inserting in lug.

3.1.11.2 Termination to Aluminum Bus

Terminate aluminum conductors to aluminum bus by using aluminum nuts, bolts, washers, and compression lugs. Wire brush and apply joint compound to conductor prior to inserting in lug. Lubricate hardware with joint compound prior to making connection. When bus contact surface is unplated, scratch-brush and coat with joint compound, without grit.

3.1.12 Covers and Device Plates

Install with edges in continuous contact with finished wall surfaces without use of mats or similar devices. Plaster fillings are not permitted. Install plates with alignment tolerance of 1/16 inch. Use of sectional-type device plates are not permitted. Provide gasket for plates installed in wet locations.

3.1.13 Electrical Penetrations

Seal openings around electrical penetrations through fire resistance-rated walls, partitions, floors, or ceilings in accordance with Section 07 84 00 FIRESTOPPING.

3.1.14 Grounding and Bonding

Provide in accordance with NFPA 70 and NFPA 780. Ground exposed, non-current-carrying metallic parts of electrical equipment, metallic raceway systems, grounding conductor in metallic and nonmetallic raceways, telecommunications system grounds, and neutral conductor of wiring systems.

Make ground connection at main service equipment, and extend grounding conductor to point of entrance of metallic water service. Make connection to water pipe by suitable ground clamp or lug connection to plugged tee. If flanged pipes are encountered, make connection with lug bolted to street side of flanged connection. Supplement metallic water service grounding system with additional made electrode in compliance with NFPA 70.

Make ground connection to driven ground rods on exterior of building. Bond additional driven rods together with a minimum of 4 AWG soft bare copper wire buried to a depth of at least 12 inches. Interconnect all grounding media in or on the structure to provide a common ground potential. This includes lightning protection, electrical service, telecommunications system grounds, as well as underground metallic piping systems. Make interconnection to the gas line on the customer's side of the meter. Use main size lightning conductors for interconnecting these grounding systems to the lightning protection system. In addition to the requirements specified herein, provide telecommunications grounding in accordance with TIA-607. Where ground fault protection is employed, ensure that connection of ground and neutral does not interfere with correct operation of fault protection.

3.1.14.1 Ground Rods

Provide ground rods and measure the resistance to ground using the fall-of-potential method described in IEEE 81. Do not exceed 25 ohms under normally dry conditions for the maximum resistance of a driven ground. If this resistance cannot be obtained with a single rod, add additional rods, spaced on center. Spacing for additional rods must be a minimum of 10 feet. If the resultant resistance exceeds 25 ohms measured not less than 48 hours after rainfall, notify the Contracting Officer who will decide on the number of ground rods to add.

3.1.14.2 Grounding Connections

Make grounding connections which are buried or otherwise normally inaccessible, excepting specifically those connections for which access for periodic testing is required, by exothermic weld or high compression connector.

- a. Make exothermic welds strictly in accordance with the weld manufacturer's written recommendations. Welds which are "puffed up" or which show convex surfaces indicating improper cleaning are not acceptable. Mechanical connectors are not required at exothermic welds.
- b. Make high compression connections using a hydraulic or electric compression tool to provide the correct circumferential pressure. Provide tools and dies as recommended by the manufacturer. Use an embossing die code or other standard method to provide visible indication that a connector has been adequately compressed on the ground wire.

3.1.14.3 Ground Bus

Provide a copper ground bus in the electrical equipment rooms as indicated. Noncurrent-carrying metal parts of electrical equipment: effectively grounded by bonding to the ground bus. Bond the ground bus to both the entrance ground, and to a ground rod or rods as specified above having the upper ends terminating approximately 4 inches above the floor. Make connections and splices of the brazed, welded, bolted, or pressure-connector type, except use pressure connectors or bolted connections for connections to removable equipment.

3.1.14.4 Resistance

Maximum resistance-to-ground of grounding system: do not exceed 5 ohms under dry conditions. Where resistance obtained exceeds 5 ohms, contact Contracting Officer for further instructions.

3.1.14.5 Telecommunications System

Provide telecommunications grounding in accordance with the following:

- a. Telecommunications Grounding Busbars: Provide a Primary bonding busbar (PBB) in the telecommunications entrance facility. Install the PBB as close to the electrical service entrance grounding connection as practicable. Install Secondary bonding busbars to maintain clearances as required by NFPA 70 and insulated from its support. A minimum of 2 inches separation from the wall is recommended to allow access to the rear of the busbar and adjust the mounting height to accommodate overhead or underfloor cable routing.
- b. Telecommunications Bonding Conductors: Provide main telecommunications service equipment ground consisting of separate bonding conductor for telecommunications, between the PBB and readily accessible grounding connection of the electrical service. Grounding and bonding conductors should not be placed in ferrous metallic conduit. If it is necessary to place grounding and bonding conductors in ferrous metallic conduit that exceeds 3 feet in length, bond the conductors to each end of the conduit using a grounding bushing or a No. 6 AWG conductor, minimum.
- c. Telecommunications Grounding Connections: Telecommunications grounding connections to the PBB: utilize listed compression two-hole lugs, exothermic welding, suitable and equivalent one hole non-twisting lugs, or other irreversible compression type connections. Bond all metallic pathways, cabinets, and racks for telecommunications cabling and interconnecting hardware located within

the same room or space as the PBB to the PBB. In a metal frame (structural steel) building, where the steel framework is readily accessible within the room; bond each PBB to the vertical steel metal frame using a minimum No. 6 AWG conductor. Where the metal frame is external to the room and readily accessible, bond the metal frame to the SBB or PBB with a minimum No. 6 AWG conductor. When practicable because of shorter distances and, where horizontal steel members are permanently electrically bonded to vertical column members, the SBB may be bonded to these horizontal members in lieu of the vertical column members. All connectors used for bonding to the metal frame of a building must be listed for the intended purpose.

3.1.15 Equipment Connections

Provide power wiring for the connection of motors and control equipment under this section of the specification. Except as otherwise specifically noted or specified, automatic control wiring, control devices, and protective devices within the control circuitry are not included in this section of the specifications and are provided under the section specifying the associated equipment.

3.1.16 Government-Furnished Equipment

Contractor rough-in for Government-furnished equipment to make equipment operate as intended, including providing miscellaneous items such as plugs, receptacles, wire, cable, conduit, flexible conduit, and outlet boxes or fittings.

3.1.17 Watthour Meters

ANSI C12.1.

3.1.18 Surge Protective Devices

Connect the surge protective devices in parallel to the power source, keeping the conductors as short and straight as practically possible. Maximum allowed lead length is 3 feet avoiding 90 degree bends. Do not locate surge protective devices inside a panelboard or switchboard enclosure.

3.2 FIELD FABRICATED NAMEPLATE MOUNTING

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets. Provide nameplate on all equipment in access controlled spaces and areas.

3.3 WARNING SIGN MOUNTING

Provide the number of signs required to be readable from each accessible side. Space the signs in accordance with NFPA 70E.

3.4 FIELD APPLIED PAINTING

Paint electrical equipment as required to match finish of adjacent surfaces or to meet the indicated or specified safety criteria. Painting: as specified in Section 09 90 00 PAINTS AND COATINGS.

3.5 FIELD QUALITY CONTROL

Furnish test equipment and personnel and submit written copies of test results. Give Contracting Officer 5 working days notice prior to each test. Where applicable, test electrical equipment in accordance with NETA ATS.

3.5.1 Devices Subject to Manual Operation

Operate each device subject to manual operation at least five times, demonstrating satisfactory operation each time.

3.5.2 600-Volt Wiring Test

Test wiring rated 600 volt and less to verify that no short circuits or accidental grounds exist. Perform insulation resistance tests on wiring No. 6 AWG and larger diameter using instrument which applies voltage of 1,000 volts DC for 600 volt rated wiring and 500 volts DC for 300 volt rated wiring per NETA ATS to provide direct reading of resistance. All existing wiring to be reused must also be tested.

3.5.3 Transformer Tests

Perform the standard, not optional, tests in accordance with the Inspection and Test Procedures for transformers, dry type, air-cooled, 600 volt and below; as specified in NETA ATS. Measure primary and secondary voltages for proper tap settings. Tests need not be performed by a recognized independent testing firm or independent electrical consulting firm.

3.5.4 Ground-Fault Receptacle Test

Test ground-fault receptacles with a "load" (such as a plug in light) to verify that the "line" and "load" leads are not reversed. Press the TEST button and then the RESET button to verify by LED status that the device is a self-test model as specified in UL 943.

3.5.5 Grounding System Test

Test grounding system to ensure continuity, and that resistance to ground is not excessive. Test each ground rod for resistance to ground before making connections to rod; tie grounding system together and test for resistance to ground. Make resistance measurements in dry weather, not earlier than 48 hours after rainfall. Submit written results of each test to Contracting Officer, and indicate location of rods as well as resistance and soil conditions at time measurements were made.

3.5.6 Phase Rotation Test

Perform phase rotation test to ensure proper rotation of service power prior to operation of new or reinstalled equipment using a phase rotation meter. Follow the meter manual directions performing the test.

-- End of Section --

SECTION 26 24 13

SWITCHBOARDS

08/21

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.1 (2014; Errata 2016) Electric Meters - Code for Electricity Metering

ASTM INTERNATIONAL (ASTM)

ASTM A123/A123M (2017) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

ASTM A153/A153M (2023) Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

ASTM A240/A240M (2023a) Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

ASTM A653/A653M (2023) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

ASTM A780/A780M (2020) Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

ASTM D709 (2017) Standard Specification for Laminated Thermosetting Materials

ASTM D1535 (2014; R 2018) Standard Practice for Specifying Color by the Munsell System

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 81 (2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

IEEE 100 (2000; Archived) The Authoritative Dictionary of IEEE Standards Terms

IEEE C2 (2023) National Electrical Safety Code

- IEEE C37.90.1 (2013) Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
- IEEE C57.12.28 (2014) Standard for Pad-Mounted Equipment - Enclosure Integrity
- IEEE C57.12.29 (2014) Standard for Pad-Mounted Equipment - Enclosure Integrity for Coastal Environments

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

- NETA ATS (2021) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

- ANSI/NEMA PB 2.1 (2023) General Instructions for Proper Handling, Installation, Operation and Maintenance of Deadfront Distribution Switchboards Rated 600 V or Less
- NEMA ICS 6 (1993; R 2016) Industrial Control and Systems: Enclosures
- NEMA PB 2 (2011) Deadfront Distribution Switchboards

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code

UNDERWRITERS LABORATORIES (UL)

- UL 467 (2022) UL Standard for Safety Grounding and Bonding Equipment
- UL 489 (2016; Rev 2019) UL Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
- UL 891 (2019) UL Standard for Safety Switchboards

1.2 RELATED REQUIREMENTS

Section 26 08 00 APPARATUS INSPECTION AND TESTING applies to this section, with the additions and modifications specified herein.

1.3 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, are as defined in IEEE 100.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Switchboard Drawings; G

SD-03 Product Data

Switchboard; G

SD-06 Test Reports

Switchboard Design Tests; G

Switchboard Production Tests; G

Acceptance Checks and Tests; G

SD-07 Certificates

Cybersecurity Installation Certification; G

Submit certification indicating conformance with the paragraph CYBERSECURITY INSTALLATION CERTIFICATION.

SD-10 Operation and Maintenance Data

Switchboard Operation and Maintenance, Data Package 5; G

SD-11 Closeout Submittals

Assembled Operation and Maintenance Manuals; G

Equipment Test Schedule; G

Required Settings; G

Service Entrance Available Fault Current Label; G

1.5 QUALITY ASSURANCE

1.5.1 Product Data

Include manufacturer's information on each submittal for each component, device and accessory provided with the switchboard including:

- a. Circuit breaker type, interrupting rating, and trip devices, including available settings.
- b. Manufacturer's instruction manuals and published time-current curves

(in electronic format) of the main secondary breaker and largest secondary feeder device.

1.5.2 Switchboard Drawings

Include wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Identify circuit terminals on wiring diagrams and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Indicate on the drawings adequate clearance for operation, maintenance, and replacement of operating equipment devices. Include the nameplate data, size, and capacity on submittal. Also include applicable federal, military, industry, and technical society publication references on submittals. Include the following:

- a. One-line diagram including breakers, fuses, current transformers, and meters.
- b. Outline drawings including front elevation, section views, footprint, and overall dimensions.
- c. Bus configuration including dimensions and ampere ratings of bus bars.
- d. Markings and NEMA nameplate data, including fuse information (manufacturer's name, catalog number, and ratings).
- e. Circuit breaker type, interrupting rating, and trip devices, including available settings.
- f. Wiring diagrams and elementary diagrams with terminals identified, and indicating prewired interconnections between items of equipment and the interconnection between the items.
- g. Manufacturer's instruction manuals and published time-current curves (in electronic format) of the main secondary breaker and largest secondary feeder device. Use this information (designer of record) to provide breaker settings that ensures protection and coordination are achieved.

1.5.3 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" or "must" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Provide equipment, materials, installation, and workmanship in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.5.4 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship, and:

- a. Have been in satisfactory commercial or industrial use for 2 years

prior to bid opening including applications of equipment and materials under similar circumstances and of similar size.

- b. Have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period.
- c. Where two or more items of the same class of equipment are required, provide products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.5.4.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.5.4.2 Material and Equipment Manufacturing Date

Products manufactured more than one year prior to date of delivery to site are not acceptable.

1.6 MAINTENANCE

1.6.1 Switchboard Operation and Maintenance Data

Submit Operation and Maintenance Manuals in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

1.6.2 Assembled Operation and Maintenance Manuals

Assemble and securely bind manuals in durable, hard covered, water resistant binders. Assemble and index the manuals in the following order with a table of contents:

- a. Manufacturer's O&M information required by the paragraph SD-10, OPERATION AND MAINTENANCE DATA.
- b. Catalog data required by the paragraph SD-03, PRODUCT DATA.
- c. Drawings required by the paragraph SD-02, SHOP DRAWINGS.
- d. Prices for spare parts and supply list.
- e. Design test reports.
- f. Production test reports.

1.7 WARRANTY

Provide equipment items that are supported by service organizations reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

PART 2 PRODUCTS

2.1 PRODUCT COORDINATION

Products and materials not considered to be switchboards and related accessories are specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION, and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.2 SWITCHBOARD

NEMA PB 2 and UL 891.

2.2.1 Ratings

Provide equipment with the following ratings:

- a. Voltage rating: 480Y/277 volts AC, three-phase, 4-wire.
- b. Continuous current rating of the main bus: as indicated.
- c. Short-circuit current rating: as indicated.
- d. UL listed and labeled as service entrance equipment.

2.2.2 Construction

Provide the following:

- a. Switchboard: consisting of one or more vertical sections bolted together to form a rigid assembly and aligned.
- b. All circuit breakers: front accessible.
- c. Rear aligned switchboards: front accessible load connections.
- e. Where indicated, "space for future" or "space" means to include a vertical bus provided behind a blank front cover. Where indicated, "provision for future" means full hardware provided to mount a breaker suitable for the location.
- f. Completely factory engineered and assembled, including protective devices and equipment indicated with necessary interconnections, instrumentation, and control wiring.

2.2.2.1 Enclosure

Provide the following:

- a. Enclosure: NEMA ICS 6 Type 1 fabricated entirely of 12 gauge ASTM A240/A240M type 304 or 304L stainless steel.
- b. Enclosure: bolted together with removable bolt-on side and rear covers, and sloping roof downward toward rear.
- e. Bases, frames and channels of enclosure: corrosion resistant and fabricated of galvanized steel. Separate sections using vertical steel barriers.
- f. Base: includes any part of enclosure that is within 3 inches of

concrete pad.

- g. Galvanized steel: ASTM A123/A123M, ASTM A653/A653M G90 coating, and ASTM A153/A153M, as applicable. Galvanize after fabrication where practicable.
- h. Paint color: ASTM D1535 light gray No. 61 or No. 49 over rust inhibitor.
- i. Paint coating system: comply with IEEE C57.12.28 for galvanized steel and IEEE C57.12.29 for stainless steel.

2.2.2.2 Bus Bars

Provide the following:

- a. Bus bars: copper with silver-plated contact surfaces.
 - (1) Phase bus bars: uninsulated.
 - (2) Neutral bus: rated 100 percent of the main bus continuous current rating as indicated.
- b. Make bus connections and joints with hardened steel bolts.
- c. Main-bus (through bus): rated at the full ampacity of the main throughout the switchboard.
- d. Minimum one-quarter by 2 inch copper ground bus secured to each vertical section along the entire length of the switchboard.

2.2.2.3 Main Section

Provide the main section consisting of a combination section with molded-case circuit breakers for the main and branch devices as indicated.

2.2.2.4 Distribution Sections

Provide the distribution sections as indicated.

2.2.2.5 Auxiliary Sections

Provide auxiliary sections consisting of indicated instruments and metering equipment as indicated.

2.2.2.6 Handles

Provide handles for individually mounted devices of the same design and method of external operation. Label handles prominently to indicate device ampere rating, color coded for device type. Identify ON-OFF indication by handle position and by prominent marking.

2.2.3 Protective Device

Provide main and branch protective devices as indicated.

2.2.3.1 Molded-Case Circuit Breaker

Provide the following:

- a. UL 489. UL listed and labeled, 100 percent rated main breaker, standard rated branch breakers, manually operated, low voltage molded-case circuit breaker, with a short-circuit current rating as indicated.
- b. Breaker frame size: as indicated.
- c. Series rated circuit breakers are unacceptable.

2.2.4 Metering

2.2.4.1 Digital Meters

IEEE C37.90.1 for surge withstand. Provide true rms, plus/minus one percent accuracy, programmable, microprocessor-based meter enclosed in a sealed case with the following features.

- a. Display capability:
 - (1) Multi-Function Meter: Display a selected phase to neutral voltage, phase to phase voltage, percent phase to neutral voltage THD, percent phase to phase voltage THD; a selected phase current, neutral current, percent phase current THD, percent neutral current; selected total PF, kW, KVA, kVAR, FREQ, kVAh, kWh. Detected alarm conditions include over/under current, over/under voltage, over/under KVA, over/under frequency, over/under selected PF/kVAR, voltage phase reversal, voltage imbalance, reverse power, over percent THD. Include a Form C KYZ pulse output relay on the meter.
 - (2) Power Meter: Display Watts, VARs, and selected KVA/PF. Detected alarm conditions include over/under KVA, over/under PF, over/under VARs, over/under reverse power.
 - (3) Volt Meter: Provide capability to be selectable between display of the three phases of phase to neutral voltages and display of the three phases of the phase to phase voltages. Detected alarm conditions include over/under voltage, over/under voltage imbalance, over percent THD.
 - (4) Ammeter: Display phase A, B, and C currents. Detected alarm conditions include over/under current, over percent THD.
 - (5) Digital Watthour Meter: Provide a single selectable display for watts, total kilowatt hours (kWh) and watt demand (Wd). Include a Form C KYZ pulse output relay on the meter.
- b. Design meters to accept input from standard 5A secondary instrument transformers.
- c. Provide programming via a front panel display and a communication interface accessible by a computer.
- d. Provide password secured programming stored in non-volatile EEPROM memory.
- e. Provide digital communications in a Modbus RTU protocol via a RS485 serial port RS485 serial port.

- f. Provide meter that calculates and stores average max/min demand values with time and date for all readings based on a user selectable sliding window averaging period.
- g. Provide meter with programmable hi/low set limits with two Form C dry contact relays when exceeding alarm conditions.
- h. Provide meter with a display of Total Harmonic Distortion (THD) measurement to a minimum of the thirty-first order.
- i. Include historical trend logging capability with the ability to store up to 100,000 data points with intervals of 1 second to 180 minutes. Provide a unit that can store and time stamp up to 1000 programmable triggered conditions.
- j. Provide event waveform recording triggered by the rms of 2 cycles of voltage or current exceeding programmable set points. Store waveforms for all 6 channels of voltage and current for a minimum of 10 cycles prior to the event and 50 cycles past the event.

2.2.4.2 Electronic Watthour Meter

ANSI C12.1. Provide a switchboard style electronic programmable watthour meter, semi-flush mounted, as indicated. Meter can be either programmed at the factory or programmed in the field. Turn field programming device over to the Contracting Officer at completion of project. Coordinate meter to system requirements.

- a. Design: Provide meter designed for use on a 3-phase, 4-wire, 480Y/277 volt system with 3 current transformers. Include necessary KYZ pulse initiation hardware for Energy Monitoring and Control System (EMCS).
- b. Coordination: Provide meter coordinated with ratios of current transformers and transformer secondary voltage.
- c. Class: 20. Accuracy: plus or minus 1.0 percent. Finish: Class II.
- d. Kilowatt-hour Register: five digit electronic programmable type.
- e. Demand Register:
 - (1) Provide solid state.
 - (2) Meter reading multiplier: Indicate multiplier on the meter face.
 - (3) Demand interval length: programmed for 60 minutes with rolling demand up to six subintervals per interval.
- f. Meter fusing: Provide a fuse block mounted in the metering compartment containing one fuse per phase to protect the voltage input to the watthour meter. Size fuses as recommended by the meter manufacturer.
- g. Provide meter with a communications port, RS485, with Modbus RTU serial or Ethernet, Modbus-TCP communications.

2.2.5 Terminal Boards

Provide with engraved plastic terminal strips and screw type terminals for external wiring between components and for internal wiring between removable assemblies. Provide short-circuiting type terminal boards associated with current transformer. Terminate conductors for current transformers with ring-tongue lugs. Provide terminal board identification that is identical in similar units. Provide color coded external wiring that is color coded consistently for similar terminal boards.

2.2.6 Wire Marking

Mark control and metering conductors at each end. Provide factory installed, white, plastic tubing, heat stamped with black block type letters on factory-installed wiring. On field-installed wiring, provide white, preprinted, polyvinyl chloride (PVC) sleeves, heat stamped with black block type letters. Provide a single letter or number on each sleeve, elliptically shaped to securely grip the wire, and keyed in such a manner to ensure alignment with adjacent sleeves. Provide specific wire markings using the appropriate combination of individual sleeves. Indicate on each wire marker the device or equipment, including specific terminal number to which the remote end of the wire is attached.

2.3 MANUFACTURER'S NAMEPLATE

Provide a nameplate on each item of equipment bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent is not acceptable. This nameplate and method of attachment may be the manufacturer's standard if it contains the required information.

2.4 FIELD FABRICATED NAMEPLATES

ASTM D709. Provide laminated plastic nameplates for each switchboard, equipment enclosure, relay, switch, and device; as specified in this section or as indicated on the drawings. Identify on each nameplate inscription the function and, when applicable, the position. Provide nameplates of melamine plastic, 0.125 inch thick, white with black center core. Provide matte finish surface. Provide square corners. Accurately align lettering and engrave into the core. Provide nameplates with minimum size of one by 2.5 inches. Provide lettering that is a minimum of 0.25 inch high normal block style.

2.5 SOURCE QUALITY CONTROL

2.5.1 Equipment Test Schedule

The Government reserves the right to witness tests. Provide equipment test schedules for tests to be performed at the manufacturer's test facility. Submit required test schedule and location, and notify the Contracting Officer 30 calendar days before scheduled test date. Notify Contracting Officer 15 calendar days in advance of changes to scheduled date.

Provide the following as part of test equipment calibration:

- a. Provide a calibration program which assures that all applicable test instruments are maintained within rated accuracy.

- b. Accuracy: Traceable to the National Institute of Standards and Technology.
- c. Instrument calibration frequency schedule: less than or equal to 12 months for both test floor instruments and leased specialty equipment.
- d. Dated calibration labels: visible on all test equipment.
- e. Calibrating standard: higher accuracy than that of the instrument tested.
- f. Keep up-to-date records that indicate dates and test results of instruments calibrated or tested. For instruments calibrated by the manufacturer on a routine basis, in lieu of third party calibration, include the following:
 - (1) Maintain up-to-date instrument calibration instructions and procedures for each test instrument.
 - (2) Identify the third party/laboratory calibrated instrument to verify that calibrating standard is met.

2.5.2 Switchboard Design Tests

NEMA PB 2 and UL 891.

2.5.2.1 Design Tests

Furnish documentation showing the results of design tests on a product of the same series and rating as that provided by this specification.

- a. Short-circuit current test.
- b. Enclosure tests.
- c. Dielectric test.

2.5.2.2 Additional Design Tests

In addition to normal design tests, perform the following tests on the actual equipment. Furnish reports which include results of design tests performed on the actual equipment.

- a. Temperature rise tests.
- b. Continuous current.

2.5.3 Switchboard Production Tests

NEMA PB 2 and UL 891. Furnish reports which include results of production tests performed on the actual equipment for this project. These tests include:

- a. 60-hertz dielectric tests.
- b. Mechanical operation tests.
- c. Electrical operation and control wiring tests.

d. Ground fault sensing equipment test.

2.6 COORDINATED POWER SYSTEM PROTECTION

Provide a power system study as specified in Section 26 05 73 POWER SYSTEM STUDIES.

2.7 ARC FLASH WARNING LABEL

Provide warning label for switchboards. Locate this self-adhesive warning label on the outside of the enclosure warning of potential electrical arc flash hazards and appropriate PPE required. Provide label format as indicated.

2.8 SERVICE ENTRANCE AVAILABLE FAULT CURRENT LABEL

Provide label on exterior of switchboards used as service equipment listing the maximum available fault current at that location. Include on the label the date that the fault calculation was performed and the contact information for the organization that completed the calculation. Locate this self-adhesive warning label on the outside of the switchboard. Provide label format as indicated.

2.9 MIMIC BUS LABELING

Provide a mimic bus on the front of the equipment to diagrammatically show the internal bus structure of the lineup.

PART 3 EXECUTION

3.1 INSTALLATION

Conform to IEEE C2, NFPA 70, and to the requirements specified herein. Provide new equipment and materials unless indicated or specified otherwise.

3.2 GROUNDING

NFPA 70 and IEEE C2, except that grounds and grounding systems with a resistance to solid earth ground not exceeding 25 ohms.

3.2.1 Grounding Electrodes

Provide driven ground rods as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION. Connect ground conductors to the upper end of the ground rods by exothermic weld or compression connector. Provide compression connectors at equipment end of ground conductors.

3.2.2 Equipment Grounding

Provide bare copper cable not smaller than No. 4/0 AWG not less than 24 inches below grade connecting to the indicated ground rods. When work in addition to that indicated or specified is directed to obtain the specified ground resistance, the provision of the contract covering "Changes" applies.

3.2.3 Connections

Make joints in grounding conductors and loops by exothermic weld or compression connector. Install exothermic welds and compression connectors as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

3.2.4 Grounding and Bonding Equipment

UL 467, except as indicated or specified otherwise.

3.3 INSTALLATION OF EQUIPMENT AND ASSEMBLIES

Install and connect equipment furnished under this section as indicated on project drawings, the approved shop drawings, and as specified herein.

3.3.1 Switchboard

ANSI/NEMA PB 2.1.

3.3.2 Meters and Instrument Transformers

ANSI C12.1.

3.3.3 Field Applied Painting

Where field painting of enclosures is required to correct damage to the manufacturer's factory applied coatings, provide manufacturer's recommended coatings and apply in accordance with manufacturer's instructions.

3.3.4 Galvanizing Repair

Repair damage to galvanized coatings using ASTM A780/A780M, zinc rich paint, for galvanizing damaged by handling, transporting, cutting, welding, or bolting. Do not heat surfaces that repair paint has been applied to.

3.3.5 Field Fabricated Nameplate Mounting

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

3.4 FOUNDATION FOR EQUIPMENT AND ASSEMBLIES

3.4.1 Exterior Location

Mount switchboard on concrete slab as follows:

- a. Unless otherwise indicated, provide the slab with dimensions at least 8 inches thick, reinforced with a 6 by 6 inch No. 6 mesh placed uniformly 4 inches from the top of the slab.
- b. Place slab on a 6 inch thick, well-compacted gravel base.
- c. Install slab such that the top of the concrete slab is approximately 4 inches above the finished grade.

- d. Provide edges above grade 1/2 inch chamfer.
- e. Provide slab of adequate size to project at least 8 inches beyond the equipment.
- f. Provide conduit turnups and cable entrance space required by the equipment to be mounted.
- g. Seal voids around conduit openings in slab with water- and oil-resistant caulking or sealant.
- h. Cut off and bush conduits 3 inches above slab surface.
- i. Provide concrete work as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE.

3.4.2 Interior Location

Mount switchboard on concrete slab as follows:

- a. Unless otherwise indicated, provide the slab with dimensions at least 4 inches thick.
- b. Install slab such that the top of the concrete slab is approximately 4 inches above the finished grade.
- c. Provide edges above grade 1/2 inch chamfer.
- d. Provide slab of adequate size to project at least 8 inches beyond the equipment.
- e. Provide conduit turnups and cable entrance space required by the equipment to be mounted.
- f. Seal voids around conduit openings in slab with water- and oil-resistant caulking or sealant.
- g. Cut off and bush conduits 3 inches above slab surface.
- h. Provide concrete work as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE.

3.5 FIELD QUALITY CONTROL

Submit Required Settings of breakers to the Contracting Officer after approval of switchboard and at least 30 days in advance of their requirement.

3.5.1 Performance of Acceptance Checks and Tests

Perform in accordance with the manufacturer's recommendations and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS.

3.5.1.1 Switchboard Assemblies

- a. Visual and Mechanical Inspection
 - (1) Compare equipment nameplate data with specifications and approved

shop drawings.

- (2) Inspect physical, electrical, and mechanical condition.
- (3) Verify appropriate anchorage, required area clearances, and correct alignment.
- (4) Clean switchboard and verify shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.
- (5) Inspect all doors, panels, and sections for paint, dents, scratches, fit, and missing hardware.
- (6) Verify that circuit breaker sizes and types correspond to approved shop drawings as well as to the circuit breaker's address for microprocessor-communication packages.
- (7) Verify that current transformer ratios correspond to approved shop drawings.
- (8) Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.
- (9) Confirm correct operation and sequencing of electrical and mechanical interlock systems.
- (10) Confirm correct application of manufacturer's recommended lubricants.
- (11) Inspect insulators for evidence of physical damage or contaminated surfaces.
- (12) Verify correct barrier installation and operation.
- (13) Exercise all active components.
- (14) Inspect all mechanical indicating devices for correct operation.
- (15) Verify that filters are in place and vents are clear.
- (16) Test operation, alignment, and penetration of instrument transformer withdrawal disconnects.
- (17) Inspect control power transformers.

b. Electrical Tests

- (1) Perform insulation-resistance tests on each bus section.
- (2) Perform dielectric withstand voltage tests.
- (3) Perform insulation-resistance test on control wiring; Do not perform this test on wiring connected to solid-state components.
- (4) Perform control wiring performance test.
- (5) Perform primary current injection tests on the entire current

circuit in each section of assembly.

3.5.1.2 Circuit Breakers - Low Voltage - Power

a. Visual and Mechanical Inspection

- (1) Compare nameplate data with specifications and approved shop drawings.
- (2) Inspect physical and mechanical condition.
- (3) Inspect anchorage, alignment, and grounding.
- (4) Verify that all maintenance devices are available for servicing and operating the breaker.
- (5) Inspect arc chutes.
- (6) Inspect moving and stationary contacts for condition, wear, and alignment.
- (7) Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
- (8) Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism.
- (9) Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.
- (10) Verify cell fit and element alignment.
- (11) Verify racking mechanism.
- (12) Confirm correct application of manufacturer's recommended lubricants.

b. Electrical Tests

- (1) Perform contact-resistance tests on each breaker.
- (2) Perform insulation-resistance tests.
- (3) Adjust Breaker(s) for final settings in accordance with Government provided settings.
- (4) Determine long-time minimum pickup current by primary current injection.
- (5) Determine long-time delay by primary current injection.
- (6) Determine short-time pickup and delay by primary current injection.
- (7) Determine ground-fault pickup and delay by primary current injection.

- (8) Determine instantaneous pickup value by primary current injection.
- (9) Activate auxiliary protective devices, such as ground-fault or undervoltage relays, to ensure operation of shunt trip devices; Check the operation of electrically-operated breakers in their cubicle.
- (10) Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and antipump function.
- (11) Verify operation of charging mechanism.

3.5.1.3 Circuit Breakers

Low Voltage Molded Case with Solid State Trips

a. Visual and Mechanical Inspection

- (1) Compare nameplate data with specifications and approved shop drawings.
- (2) Inspect circuit breaker for correct mounting.
- (3) Operate circuit breaker to ensure smooth operation.
- (4) Inspect case for cracks or other defects.
- (5) Inspect all bolted electrical connections for high resistance using low resistance ohmmeter, verifying tightness of accessible bolted connections and/or cable connections by calibrated torque-wrench method, or performing thermographic survey.
- (6) Inspect mechanism contacts and arc chutes in unsealed units.

b. Electrical Tests

- (1) Perform contact-resistance tests.
- (2) Perform insulation-resistance tests.
- (3) Perform Breaker adjustments for final settings in accordance with Government provided settings.
- (4) Perform long-time delay time-current characteristic tests
- (5) Determine short-time pickup and delay by primary current injection.
- (6) Determine ground-fault pickup and time delay by primary current injection.
- (7) Determine instantaneous pickup current by primary injection.
- (8) Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and anti-pump function.

3.5.1.4 Current Transformers

a. Visual and Mechanical Inspection

- (1) Compare equipment nameplate data with specifications and approved shop drawings.
- (2) Inspect physical and mechanical condition.
- (3) Verify correct connection.
- (4) Verify that adequate clearances exist between primary and secondary circuit.
- (5) Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.
- (6) Verify that all required grounding and shorting connections provide good contact.

b. Electrical Tests

- (1) Perform resistance measurements through all bolted connections with low-resistance ohmmeter, if applicable.
- (2) Perform insulation-resistance tests.
- (3) Perform polarity tests.
- (4) Perform ratio-verification tests.

3.5.1.5 Metering and Instrumentation

a. Visual and Mechanical Inspection

- (1) Compare equipment nameplate data with specifications and approved shop drawings.
- (2) Inspect physical and mechanical condition.
- (3) Verify tightness of electrical connections.

b. Electrical Tests

- (1) Determine accuracy of meters at 25, 50, 75, and 100 percent of full scale.
- (2) Calibrate watt-hour meters according to manufacturer's published data.
- (3) Verify all instrument multipliers.
- (4) Electrically confirm that current transformer and voltage transformer secondary circuits are intact.

3.5.1.6 Grounding System

a. Visual and Mechanical Inspection

- (1) Inspect ground system for compliance with contract plans and specifications.

b. Electrical Tests

- (1) IEEE 81. Perform ground-impedance measurements utilizing the fall-of-potential method. On systems consisting of interconnected ground rods, perform tests after interconnections are complete. On systems consisting of a single ground rod perform tests before any wire is connected. Take measurements in normally dry weather, not less than 48 hours after rainfall. Use a portable ground resistance tester in accordance with manufacturer's instructions to test each ground or group of grounds. Use an instrument equipped with a meter reading directly in ohms or fractions thereof to indicate the ground value of the ground rod or grounding systems under test.
- (2) Submit the measured ground resistance of each ground rod and grounding system, indicating the location of the rod and grounding system. Include the test method and test setup (i.e., pin location) used to determine ground resistance and soil conditions at the time the measurements were made.

3.5.1.7 Cybersecurity Installation Certification

Furnish a certification that control systems are installed in accordance with DoD Instruction 8500.01, DoD Instruction 8510.01, and as required by individual Service Implementation Policy.

3.5.2 Follow-Up Verification

Upon completion of acceptance checks, settings, and tests, show by demonstration in service that circuits and devices are in good operating condition and properly performing the intended function. Trip circuit breakers by operation of each protective device. Test each item to perform its function not less than three times. As an exception to requirements stated elsewhere in the contract, provide the Contracting Officer five working days advance notice of the dates and times for checks, settings, and tests.

-- End of Section --

SECTION 26 35 43

400-HERTZ (HZ) SOLID STATE FREQUENCY CONVERTER
08/21, CHG 1: 05/24

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D709 (2017) Standard Specification for Laminated Thermosetting Materials

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 100 (2000; Archived) The Authoritative Dictionary of IEEE Standards Terms

IEEE 519 (2022) Standard for Harmonic Control in Electrical Power Systems

IEEE 1159 (2019) Recommended Practice on Monitoring Electric Power Quality

IEEE C2 (2023) National Electrical Safety Code

IEEE C62.41.1 (2002; R 2008) Guide on the Surges Environment in Low-Voltage (1000 V and Less) AC Power Circuits

IEEE C62.41.2 (2002) Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250 (2020) Enclosures for Electrical Equipment (1000 Volts Maximum)

NEMA ST 20 (2014) Dry-Type Transformers for General Applications

NEMA Z535.4 (2023) Product Safety Signs and Labels

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code

NFPA 70E (2024) Standard for Electrical Safety in the Workplace

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE AS5756/6	(2013; Rev A; Stabilized (S) 2013) Cable, 3-Phase Power, Electric, Portable, Multiconductor, 90 Degree C, 600V, Ozone Resistant, Split Phase
SAE AS7974	(2010; Rev A) Cable Assemblies and Attachable Plugs, External Electrical Power, Aircraft

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-704	(2016; Rev F; Change 1; Notice 3 2021) Aircraft Electric Power Characteristics
MIL-STD-1399-300	(2018) Low Voltage Electric Power, Alternating Current - Part 1

UNDERWRITERS LABORATORIES (UL)

UL 467	(2022) UL Standard for Safety Grounding and Bonding Equipment
UL 489	(2016; Rev 2019) UL Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
UL 506	(2017; Reprint Jan 2022) UL Standard for Safety Specialty Transformers
UL 1012	(2010; Reprint Apr 2016; Rev Mar 2021) UL Standard for Safety Power Units Other than Class 2
UL 1449	(2021; Reprint Dec 2022) UL Standard for Safety Surge Protective Devices

1.2 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, must be as defined in IEEE 100.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Converter Drawings; G

SD-03 Product Data

Converter; G

Aircraft Power Cable Assembly; GSD-06 Test Reports

Work Plan; G

Routine Factory Test Plan; G

Special Factory Test Plan; G

Factory Test Schedule; G

Routine Factory Tests Certification; G

Special Factory Tests Certification; G

SD-07 Certificates

Qualifications of Manufacturer; G

Nationally Recognized Testing Laboratory (NRTL) Listing; G

SD-09 Manufacturer's Field Reports

Field Test Plan; G

Field Test Schedule; G

Field Test Certification; G

Training Syllabus; G

SD-10 Operation and Maintenance Data

Converter O&MM, Data Package 5; G

Preliminary Converter O&MM, Data Package 5; G

1.4 QUALITY ASSURANCE

1.4.1 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "must" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Equipment, materials, installation, and workmanship must be in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.4.2 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship. Products must have been in satisfactory

commercial or industrial use for 5 years prior to bid opening. The 5-year period must include applications of equipment and materials under similar circumstances and of similar size. The product must have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 5-year period. Where two or more items of the same class of equipment are required, these items must be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.4.2.1 Alternative Qualifications

Products having less than a 5-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.4.2.2 Material and Equipment Manufacturing Date

Products manufactured more than one year prior to date of delivery to site must not be used, unless specified otherwise.

1.4.3 Converter Drawings

Furnish scaled drawings of enclosure outline including front, top, side views, and overall dimensions. Include "maintenance envelope" dimensions confirming space limitations identified on the drawings, and surface mounting flush against the wall. Rear access for maintenance and repair purposes is prohibited. The "maintenance envelope" drawings must also indicate adequate clearance for operation, maintenance, and replacement of operating equipment devices. Provide external power and control wiring, cabling, connector, and backplane interconnect drawings. Provide single line, schematic, and wiring diagrams. Drawings must include details of input and output circuit breakers, contactors, rectifiers, surge protectors, control devices and conduit entry and exit locations. If parallel operation is included, provide an interconnection diagram. Submittals must include the nameplate data, size, and capacity.

1.4.4 Qualifications of Manufacturer

Submit a certification stating that the manufacturer has a minimum of five years' experience in the design, manufacturing, and testing of 400 Hz solid state frequency converters at the equivalent or greater kW and voltage ratings for direct connection to aircraft electrical loads. When specifications require multiple converters operating in parallel, the manufacturer must provide specific experience with equal or greater kW rated converters.

Experience in manufacturing motor generator sets does not qualify as equivalent. Experience in manufacturing portable engine-driven 400-hertz power units does not qualify as equivalent. The manufacturer must be experienced in producing units for installation in permanent buildings in environmentally closed spaces or in weatherproof enclosures as applicable. The manufacturer must also document that converters are designed for connection to non-linear loads typically encountered in the aircraft and shipbuilding industries. The manufacturer must furnish documented experience with converters in various environmental conditions including exterior flight line, hangar, and environmentally enclosed spaces within buildings.

1.4.5 Work Plan

Submit a written work plan with the initial shop drawing submittal, which consists of a schedule of dates of the routine and special factory tests, installation of equipment, field tests, and operator training for the system. Furnish a list of the test instrumentation equipment complete with the documented calibration program, for the factory and the field tests.

1.4.6 Routine Factory Test Plan

Submit test plan and procedures at least 21 calendar days prior to the tests being conducted. Provide detailed description of test procedures, including test equipment and setups complete with their current calibration dates, to be used to ensure the converter meets this specification and explain the test methods used. As a minimum, include the tests required under the paragraph ROUTINE FACTORY TESTS.

1.4.7 Special Factory Test Plan

Submit the Special Factory Test Plan and procedures with the Routine Factory Test Plan. Provide detailed description of test procedures, including test equipment and setups complete with their calibration dates, used to ensure the converter meets this specification and explain the test methods used. As a minimum, include the tests required under the paragraph SPECIAL FACTORY TESTS.

1.4.8 Field Test Plan

Submit test plan and procedures at least 15 calendar days prior to the start of field tests. Provide detailed description and dates and times scheduled for performance of tests, and detailed description of test procedures, including test equipment and setups of the tests to be conducted to ensure the system meets this specification. List make, model, and current calibration dates, and provide functional description of the test instruments and accessories. Explain the test methods to be used. As a minimum, include the tests required under the paragraph FIELD QUALITY CONTROL. Test reports must include power quality measurement data collected in accordance with IEEE 1159.

1.4.9 Nationally Recognized Testing Laboratory (NRTL) Listing

Frequency converters must be identified with a nationally recognized testing laboratory (NRTL) label or UL label prior to shipping.

1.4.9.1 Currently Listed Products

Submit NRTL or UL certification or UL file number for the actual frequency converter to be shipped with the initial submittal to verify compliance of equipment.

1.4.9.2 Proposed Listed Products

Submit NRTL or UL certification or UL file number for same or similar rating or product size range of like design unit with the initial submittal to verify compliance of equipment.

1.4.10 Routine Factory Tests Certification

Submit within 45 calendar days after completion of tests. Receive approval of test prior to shipping unit. Certify tests were conducted on each converter in accordance with the requirements set forth in paragraph ROUTINE FACTORY TESTS and certify converter satisfactorily operated within specified limits. Include copies of the test procedures, test configuration diagrams and schematics, test data, and results.

1.4.11 Special Factory Tests Certification

Certify tests were conducted on a converter of the same design, construction, kW rating, and voltage rating to be provided. Tests must be in accordance with the requirements set forth in paragraph SPECIAL FACTORY TEST and certify converter operated without malfunctioning within specified limits. Include copies of the test procedures, test configuration diagrams and schematics, test data, and results.

1.4.12 Field Test Certification

Submit report of test results as specified by paragraph FIELD QUALITY CONTROL within 15 calendar days after completion of tests. Certify tests were conducted on each converter in accordance with the paragraph FIELD QUALITY CONTROL and certify converter satisfactorily operated within specified limits. Include copies of the test procedures, test configuration diagrams and schematics, test data, and results.

1.5 OPERATION AND MAINTENANCE MANUALS

Submit frequency converter Operation and Maintenance Manuals (O&MM) in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

1.5.1 Additions to Converter O&MM

In addition to requirements of Data Package 5, include the following on the actual converter provided:

- a. A "one-line diagram" from the building service entrance panel to the converter and out to the end utilization point(s).
- b. A concise, duplicatable, single page data sheet with operating instructions for each unit including startup and shutdown procedures.
- c. Routine and field test reports.
- d. NRTL or UL certification or UL file number.
- e. A list of all code required identification and warning signage and labels that have been provided on the converter.

1.5.2 Preliminary Converter O&MM

Prior to scheduling Field Tests, 2 bound copies of a Preliminary O&MM must be submitted to and approved by the Contracting Officer.

1.5.3 Spare Parts Information

Furnish recommended manufacturer's spare parts list, quantities, lead time to receive after ordering, and a schedule of prices, (guaranteed for one

year after warranty expires), for each type of converter and other equipment specified in this section. Include the following:

- a. Fuses
- b. Human Machine Interface (HMI)
- c. Indicator lamp/LED
- d. Output switching modules
- e. Plug-in logic cards
- f. Power filter capacitors
- g. Power semi-conductors
- h. Ventilation system filters
- i. 400 Hz Aircraft Power Cable Assembly

1.6 WARRANTY

The equipment items must be supported by service organizations which are most convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

PART 2 PRODUCTS

2.1 FREQUENCY CONVERTER

Provide frequency converter consisting of modular construction solid-state components for 60 Hz to 400 Hz conversion, input/output devices, and ancillary control devices. Converter must be a standard product of the manufacturer and the manufacturer's latest design that complies with the specification requirements. The converters provided under this contract must be products of the same manufacturer. Each unit must have a calculated Mean Time Between Failures (MTBF) exceeding 24,000 hours as calculated when the converter is provided with yearly servicing and maintenance. Provide converter with NRTL or UL listing complying with UL 1012. The converter must have minimum 12 pulse, active input rectification circuit or a demonstrated design achieving equal or better performance characteristics. Circuit breakers operating at 400 Hz must be designed and UL tested for 60 Hz operation and derated for 400 Hz operation. Provide startup and shutdown instructions posted on the front of the unit using engraved plastic or aluminum plate. Provide a plastic encapsulated schematic diagram attached to the inside of the unit in clear view of maintenance personnel.

2.1.1 Electrical Characteristics

2.1.1.1 Input Voltage

480 V, three phase, three wire, grounded, 60 Hz. Converter must provide rated output voltage when input voltage is varied plus or minus 10 percent. A voltage changing transformer is not permitted at the input of the converter unit

2.1.1.2 Input Power Factor

Between 0.8 lagging and unity, under all conditions of steady state line and load variations specified herein.

2.1.1.3 Surge Protection

Provide converter capable of sustaining an input surge described in and tested in accordance with UL 1449, and IEEE C62.41.1 and IEEE C62.41.2, Location Category B, and continue to operate with no alarms within the specified tolerance.

2.1.1.4 Inrush Current

The inrush current must not exceed 100 percent of the rated full load input current.

2.1.1.5 Input Current Distortion

Input current Total Harmonic Distortion (THD) must not exceed 12percent of the fundamental frequency with nominal input voltage at full load. Individual harmonic content must not exceed 8 percent of the fundamental frequency.

2.1.1.6 Output Voltage

Provide a frequency converter with a 200Y/115 V, three phase, 400 Hz, grounded system, adjustable to plus or minus 10 percent of the rated voltage.

- a. The power characteristics must be within the requirements of MIL-STD-704 with the following clarifications:
 - (1) The voltage and frequency must be in accordance with the envelope of normal operating range of Figures 3 and 5, not just the limits of Figures 4 and 6.
 - (2) The steady state voltage must additionally be in accordance with the external power requirements as defined in the MIL-STD-704 Section 4.3, "External Power Source Requirement".
- b. The power characteristics must be within the requirements of MIL-STD-1399-300, Part 1, Type III power.
- c. The phase rotation of the output voltage must be A-B-C (per Figure 2 in MIL-STD-704, spinning in a counterclockwise direction).

2.1.1.7 Power Output

Provide a frequency converter rated at 90 kW at unity power factor.

2.1.1.8 Load Range

Converter must operate into a linear load with a power factor between 0.5 lagging and 0.7 leading and into a non-linear load with not less than 15 percent current THD, composed of not less than 6 percent of the 3rd harmonic and not less than 7 percent of the 5th harmonic.

2.1.1.9 Efficiency

Provide 90 kW units with a minimum efficiency of 87 percent at 50 percent load and 91 percent at 100 percent load.

2.1.1.10 No Load Input Losses

Provide frequency converter with no-load input losses no greater than 7 percent of the output kW rating.

2.1.1.11 Overload

Satisfactory overload operating time is based on no more than one overload of the same or longer conditions, within the following specified time between overloads.

<u>Percent of Full Load</u>	<u>Satisfactory Operating Time</u>	<u>Time Between Overloads</u>
110 percent	60 minutes	4 hours Note: Unit must still be capable of withstanding any of the other conditions for their respective operating times. e.g. Unit can still do 125 percent for less than 5 minutes, before tripping, etc.
125 percent	5 minutes	10 minutes
150 percent	2 minutes	10 minutes
200 percent	20 seconds	5 minutes

After minimum operating time is achieved, unit must interrupt output power. Unit must be capable of sustaining the overload without damage until the protective device interrupts the overload.

2.1.1.12 Short Circuit

When a bolted line-to-line fault or a bolted three phase fault is applied to the unit, unit must be capable of sustaining the short circuit current without damage until the protective device interrupts the fault.

2.1.1.13 Crest Factor

The voltage crest factor must be between 1.31 and 1.51 over the entire load range in accordance with MIL-STD-704. The crest factor is the ratio of the peak value to the root mean square (RMS) value for each half cycle of the voltage waveform measured over a one second period under steady state conditions. Provide the crest factor for each condition in the paragraph LOAD RANGE.

2.1.1.14 Output Voltage THD

a. Balanced load:

- (1) Output voltage THD: Not to exceed 3 percent line-to-line and line-to-neutral for linear loads as specified in the paragraph LOAD RANGE.
- (2) Output voltage THD: Not to exceed 5 percent line-to-line and line-to-neutral for non-linear loads as specified in the paragraph LOAD RANGE.
- (3) Maximum single harmonic distortion: Not to exceed 2 percent of the fundamental at the nominal voltage for linear loads as specified in the paragraph LOAD RANGE.
- (4) Maximum single harmonic distortion: Not to exceed 3 percent of the fundamental at the nominal voltage for non-linear loads as specified in the paragraph LOAD RANGE.

b. Unbalanced load: Output voltage THD not to exceed 4 percent, line-to-neutral with 15 percent unbalanced linear load.

2.1.1.15 Output Voltage Amplitude Modulation

Provide output voltage amplitude modulation not exceeding 1/2 percent of nominal voltage at no load to full load.

2.1.1.16 Frequency Stability

Control output frequency of the 400 Hz converter within plus or minus 0.5 percent for all operating conditions, including maximum and minimum specified input voltages, ambient temperature and relative humidity. The frequency regulation must operate independent of supply frequency and load changes.

2.1.1.17 Phase Angle Regulation

Displacement angle between adjacent voltage phases must be 120 degrees plus or minus 2 degrees with balanced load and plus or minus 4 degrees with three phase 15 percent unbalanced load. A 15 percent unbalanced load is defined as any combination of phasing where:

- a. Phase A at full rated single phase load.
- b. Phase B at 85 percent of Phase A.
- c. Phase C at 85 percent of Phase A.

2.1.1.18 Transient Output Voltage Recovery

In accordance with MIL-STD-704. Monitor and record output voltage at the load end of the cable.

2.1.2 Environmental Rating

The converter must be rated for continuous operation from no load to rated full load under the following conditions:

- a. Ambient temperatures ranging from -4 to 130 degrees F.
- b. Relative humidity from 0 to 95 percent noncondensing.
- c. Ambient pressures from sea level to 3,000 feet.

2.1.3 Monitoring and Control Panel

Provide converter with a control panel that is equipped with the following controls, indicators, instrumentation, data logging, diagnostics, and alarm functions.

2.1.3.1 Controls

Controls must be mounted on the front of the control panel, accessible without opening any doors or covers. Specific sequencing, or the requirement for simultaneous pushbutton operation, is not acceptable for any input or output control.

- a. Start/stop pushbutton for input device control (circuit breaker or contactor).
- b. Lamp/light emitting diode (LED) test - A push-to-test button or switch to test indicator lamps/LEDs. If panel lights all blink as part of the startup Built-in-Test (BIT) sequence, then a separate push to test button is not required.
- c. Emergency power off - A separate pushbutton for emergency power off.
- d. Output device ON/OFF.
- e. Alarm silence and "silence" indicator - A switch that must disable the audible alarm without clearing the alarm codes.
- f. Additional individual controls for the following functions (Note - these may be included as part of the Human-Machine Interface (HMI) as described in paragraph HUMAN MACHINE INTERFACE REQUIREMENTS):
 - Output voltage adjust
 - Alarm reset - resets and clears the silenced audible alarm.

2.1.3.2 Indicators

- a. The following are mandatory indicators. They must be included on the control panel on the exterior of the unit in addition to any that are included in the HMI:
 - Input power available - Lamp/LED to indicate that the supply voltage is available.
 - Output power On/Off - Lamp/LED to indicate that the converter output voltage is available.
 - Output device "ON".
 - Audible alarm.
 - Aircraft interlock bypass - Lamp/LED to indicate that the Aircraft

Interlock has been bypassed.

- b. In addition, include the following additional indicators, if they are not included in the HMI:
 - System alarm - Lamp/LED to indicate that a fault has been detected. This indicator must be latched in the "ON" position whenever an alarm condition described in paragraph ALARM ANNUNCIATOR, is detected and must remain "ON" until the alarm reset pushbutton is pressed.
 - Indicating lamp/LED to indicate that the alarm silence switch is in the disable position.
 - Elapsed time meter in hours; (may be internal or visible externally).

2.1.3.3 Human Machine Interface (HMI) Requirements

Provide an HMI with a minimum of four by twenty (4 x 20) character backlit LED display for presenting the digital instrumentation, diagnostic system, and fault indicating system data. The HMI must be rated for harsh environments.

- a. Digital Instrumentation. Provide true RMS, plus/minus one percent accuracy, microprocessor-based readings that include the following functions:
 - (1) Output phase-to-phase voltage.
 - (2) Output phase-to-neutral voltage.
 - (3) Output phase current.
 - (4) Output frequency.
 - (5) Inverter temperature. This function is desired for field diagnostics, but is not mandatory.
- b. Alarm Annunciator. The unit must be capable of detecting and displaying the following abnormal conditions:
 - (1) Input overvoltage.
 - (2) Input undervoltage.
 - (3) Output undervoltage.
 - (4) Output overvoltage.
 - (5) Output overload.
 - (6) System alarm.
 - (7) Control logic failure.
 - (8) Over-temperature.
 - (9) Logic power supply failure.

2.1.4 Input/Output Devices

Provide fully-rated, three-pole, UL approved devices for control of 60 Hz input and 400 Hz output from the converter. Derate devices and cables operating at 400 Hz in accordance with IEEE 519.

2.1.4.1 Input Device

Provide converter with a UL listed input device (circuit breaker conforming to requirements of UL 489 or contactor) as an integral part of the converter. Device must be operable from the front of the converter. Device must have a short-circuit current rating of 50,000 amperes symmetrical minimum.

2.1.4.2 Output Contactor

Provide converter output with an automatic magnetically-held contactor with interlock circuit. Output contactor must have sufficient capacity to handle rated load, overload, and available short circuit current. Contactor must open when any circuit identified in the paragraph SAFETY FUNCTIONS causes the system to shut down. Electrically interlock contactor with ON/OFF circuitry so that when the frequency converter is shut down, the contactor opens immediately and remains open.

2.1.4.3 Aircraft Interlock Circuit

Provide interlock system that determines the presence or absence of the 28 VDC feedback signal from the aircraft. If the 28 VDC signal is not present within 5 seconds after initially closing the output disconnect, open the output disconnect. Once the interlock signal is received and the system is in operation, if the interlock signal is lost, the converter control system must remove the 400 Hz power from the output servicing cable connector within 100 milliseconds.

- a. Converter must contain terminal block points for the connection of two wires from the aircraft cable assembly for the interlock circuit (sized to accept No. 18 and No. 12 AWG). Interlock circuit must not draw more than 20 milliamperes from the aircraft's 28 VDC circuit.
- b. For field testing purposes, provide a switch inside the converter with two positions:
 - (1) Normal - For aircraft loads.
 - (2) Bypass - For testing with dummy load or no load, or for use with aircraft with no 28 VDC. This switch needs to be "Inside" or "located within the HMI functions". It must be out of sight except for specific maintenance purposes.

2.1.5 Safety Functions

2.1.5.1 400 Hz Power Source

The 400 Hz power source internal buss must automatically discharge to below 30 VAC within 5 seconds after the following:

- a. 400 Hz power source has been turned off.
- b. Whenever any access panel is opened on the equipment. Under this

condition, the interlock circuitry must open the input device and the 400 Hz output device, and not allow the input or output device to close. For maintenance purposes, provide an internal bypass switch to defeat the interlock circuitry.

- c. Detection of system fault that results in a converter shut down condition, including the following:

- (1) Input undervoltage.
- (2) Input overvoltage.
- (3) Loss of phase (input or output).
- (4) Loss of input power.

2.1.5.2 400 Hz Output Cable

The 400 Hz power must be removed from the output cable within 100 milliseconds after one of the following occurs:

- a. Receiving a stop command.
- b. Loss of 28 VDC control signal.
- c. Detection of a fault that results in an output shut down, including the following:
 - (1) Output overvoltage - Protect by tripping output devices for instantaneous overvoltage of 30 percent or more and for 10 to 30 percent overvoltage lasting more than 0.25 seconds.
 - (2) Output undervoltage - Protect by preventing the closing of the output disconnect until the output voltage is 95 percent of the rated output. If, after closing, the voltage decreases to below 90 percent for longer than 5 seconds, provide relaying to trip output devices utilizing a field-adjustable time-delayed circuit with a range of 4 to 10 seconds.
 - (3) Output frequency - Protect by tripping output devices for frequency change in excess of plus or minus 5 percent of the rated output frequency (400 Hz).
 - (4) Output overload.
 - (5) Converter overtemperature protection.

2.1.6 Automatic Line Drop Compensation

Provide automatic line drop compensation from zero to ten percent; adjustable internally.

2.1.7 Auto Restart

After a total input power outage the unit must be capable of automatically restarting and re-energizing loads upon restoration of normal power. Provide units with a manual/auto restart switch and with backup battery power supply if it is needed to meet the auto restart requirement. When interlock circuit has been interrupted or when interlock is in the

maintenance position (manual restart), the system should not restart.

2.1.8 Magnetic Components

Provide Class 180 power magnetic transformer and inductors in accordance with NEMA ST 20 and UL 506. The limits of Class 180 must not be exceeded at the maximum specified ambient temperature and at 100 percent load.

2.1.9 Acoustical Noise

Provide unit with a maximum continuous acoustical noise level less than 72 dBa (A weighted scale).

2.1.10 Assembly Construction

Provide enclosures suitable for corrosive environments in accordance with NEMA 250, Type 3RX. Arrange to provide required louvers, cooling air, entry and exit provisions for equipment within enclosures.

- a. Units must be mounted flush against the wall, must not require back access for maintenance, and must comply with the "Maintenance Envelopes" identified on the drawings.
- b. Construct unit(s) so that components, with the exception of control and monitoring components, are totally enclosed within the enclosure. Electronic circuits including power circuits must be modular construction readily accessible for maintenance, repair and module replacement from the front of the enclosure. For units installed outdoors or in corrosive environments, provide a conformal (rust-inhibiting) coating for the printed circuit boards.
- c. Provide permanent identification tags for wiring. Uniquely identify each wire. Use the same identification system in the wiring diagrams in the Operation and Maintenance Manual. Enclosures must be painted in accordance with paragraph FACTORY APPLIED FINISH and as specified herein. Provide each enclosure with a finish coat over a rust inhibiting substrate or a substrate that has been provided with a rust inhibiting treatment.
- d. Provide units with a Mean Time To Repair (MTTR) of 30 minutes from the time of the diagnosed failure based on documented manufacturer's historical data for the average time of repair for their top ten faults. Provide the supporting data with the equipment submittal.

2.2 AIRCRAFT POWER CABLE ASSEMBLY

Comply with SAE AS7974. For 400 Hz wiring at 200Y/115 volts, provide 7-conductor type cable configured as 6 phase conductors (2xA, 2xB, 2xC) tightly wound around the center located neutral, twisted and single jacketed in accordance with SAE AS5756/6. Rate cable for 260amperes. Cable length must be 90 feet. Provide control cabling included within the jacket for interlock circuit. Terminate control wiring on accessible terminal blocks in unit. Provide cable assembly with integrally molded 400 Hertz connector capable of connecting to the aircraft 6 pole receptacle. Provide cable/connector assembly suitable for severe duty, with crimped contact terminations. Banded cables are not permitted.

2.3 MANUFACTURER'S NAMEPLATE

Each frequency converter, each major component within the frequency converter, and each item of other equipment must have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

2.4 FACTORY APPLIED FINISH

Electrical equipment must have factory-applied painting systems which must, as a minimum, meet the requirements of NEMA 250 corrosion-resistance test and the additional requirements as specified herein. Interior and exterior steel surfaces of equipment enclosures must be thoroughly cleaned and then receive a rust-inhibitive phosphatizing treatment, a primer powder coat, or equivalent treatment prior to painting. Exterior surfaces must be free from holes, seams, dents, weld marks, loose scale or other imperfections. Interior surfaces must receive not less than one coat of corrosion-resisting paint or powder coating process in accordance with the manufacturer's standard practice. When enclosure is aluminum, interior may optionally be coated with rust inhibiting treated film. Exterior surfaces must be primed, filled where necessary, and given not less than two coats baked enamel with semigloss finish, or finished with a powder coating process. Provide manufacturer's coatings for touch-up work and as specified in paragraph FIELD APPLIED PAINTING.

2.5 SOURCE QUALITY CONTROL

2.5.1 Factory Test Schedule

The Government reserves the right to witness tests and reserves the right to request the raw data from the tests whether witnessed or not. Provide the frequency converter test schedule for tests to be performed at the manufacturer's test facility. Submit required test schedule and location, and notify the Contracting Officer 30 calendar days before scheduled test date. Notify Contracting Officer 15 calendar days in advance of changes to scheduled date.

Test Instrument Calibration.

- a. The manufacturer must have a documented calibration program which assures that all applicable test instruments are maintained within rated accuracy.
- b. The accuracy must be directly traceable to the National Institute of Standards and Technology.
- c. Instrument calibration frequency schedule must not exceed 12 months for both test floor instruments and leased specialty equipment.
- d. Provide dated calibration labels, that are visible on all test equipment.
- e. Calibrating standard must be of higher accuracy than that of the instrument tested.
- f. Keep up-to-date records that indicate dates and test results of instruments calibrated or tested. For instruments calibrated by the manufacturer on a routine basis, in lieu of third party calibration,

include the following:

- (1) Maintain up-to-date instrument calibration instructions and procedures for each test instrument.
- (2) Identify the third party/laboratory calibrated instrument to verify that calibrating standard is met.

2.5.2 Routine Factory Tests

Perform routine tests by the manufacturer at the factory, on each of the actual frequency converter(s) prepared for this project to ensure that the design performance is maintained in production. Submit test reports, by serial number and receive approval before delivery of equipment to the project site. Include a list of the current test equipment calibration dates. Required tests, test conditions, and testing sequence is as follows:

- a. For tests which require full load, use 1.0 power factor unless otherwise noted.
- b. All measurements must be true RMS measurements. Obtain measurements in accordance with IEEE 1159. Monitor and record all data at the load end of the cable.
- c. Connect loads to the converter with the specified aircraft power cable assembly.
- d. No adjustments to the frequency converter are allowed between load tests.

2.5.2.1 Test Conditions

Tests must include the following conditions:

- a. Initial Safety Verification: Perform tests and checks to validate the safe and timely shutdown for each condition (for the power source and the output cable) identified in paragraph SAFETY FUNCTIONS.
- b. Input current and power factor: Operate converter at low, nominal and high input voltage at full load. Measure and record input voltage, input power factor and input current in each phase.
- c. Output voltage, output voltage THD, output current, output power factor, and voltage regulation. Operate converter at nominal input voltage unless otherwise specified.
 - (1) 50 percent of rated capacity with 0.8 lagging power factor linear load.
 - (2) 100 percent of rated capacity with 0.5 lagging power factor, 0.8 lagging power factor, 1.0 power factor, and 0.7 leading power factor linear loads.
 - (3) 50 percent of rated capacity with the non-linear load as specified in the paragraph LOAD RANGE.
 - (4) 100 percent of rated capacity at low and high input voltage.

- (5) 100 percent of rated capacity with the non-linear load as specified in the paragraph LOAD RANGE.
- (6) Note - Operate for not less than 10 minutes at each test condition in (1), (2), (3) and (4) above, and for not less than 30 minutes at test condition in (5) above.
- (7) Note - Monitor and record each of the following at the beginning and end of each test condition: output voltage, output voltage waveform, output voltage THD, output voltage distortion spectrum, output voltage crest factor, output current, output current waveform, output current distortion spectrum, output power factor and frequency. Verify output remains within specified regulation limits.
- d. Efficiency: Operate at nominal input voltage at half load and full load at 1.0 power factor. Measure and record input voltage, input current, input power factor, output voltage, output current, and output power factor. Calculate the unit efficiency.
- e. No load losses: Operate at no load and nominal input voltage. Measure and record input voltage, input current, input power, input power factor, and output voltage. Calculate the no load losses.
- f. Overload: Operate at nominal input voltage and output voltage with loads and in sequence listed below:

Percent of Full Load	Time	Time Between Overloads	Iterations
200 percent	20 seconds	5 minutes	1
150 percent	2 minutes	10 minutes	1
125 percent	5 minutes	10 minutes	1
110 percent	60 minutes	4 hours	1

- Monitor output to confirm there is no 400 Hz power interruption. After minimum operating time is achieved, unit must interrupt output power. Provide voltage and current waveforms documenting the unit's response for each test.
- g. Burn-in Test: Before delivery, burn-in all units under full load conditions at 1.0 power factor for at least 24 hours by cycling units 6 hours "ON" under full load conditions and 3 hours "OFF" at no load conditions for at least 4 complete "ON" cycles. Perform burn-in test with the converter enclosure doors closed, load connected directly to the output terminals, and all ventilation in the final operating condition. The specified aircraft cable is not required to be used for this test.
- h. Include harmonic frequency spectrum analysis depicting harmonic order across the range of individual harmonic occurrence, harmonic magnitude, and frequency range of individual harmonic occurrence for each load condition in the test reports. Conduct tests at the unit's input terminals (to the 37th harmonic), and at the units output terminals (to the 37th harmonic) per IEEE standards.
- i. Automatic line drop compensation: Operate converter at nominal voltage and verify specified performance of the line drop compensation

at the following loads.

- (1) No-load.
 - (2) 50 percent of rated capacity with a 0.8 lagging power factor linear load.
 - (3) 50 percent of rated capacity with the specified non-linear load.
 - (4) 100 percent of rated capacity with a 0.8 lagging power factor linear load.
 - (5) 100 percent of rated capacity with the specified non-linear load.
- j. Post Routine Test Safety Verification: Repeat tests conducted under item a. Initial Safety Validation to confirm safety features were not affected by previous tests.

2.5.3 Special Factory Tests (Design Tests)

Submit special factory test (design test) reports (complete with test data, explanations, formulas, results, setup and cable information, and the list of the calibration dates of the test equipment used), in the same submittal package as the catalog data and drawings for each of the specified frequency converter(s). Tests must be certified and signed by a registered professional engineer or by a "company certified professional designee" within the manufacturers' organization. Submit designee's credentials with the initial design test report for approval. Tests must be on file based on a production model of converters of the same design, construction and kW rating provided.

To assure compliance with the specification, these tests are also subject to government witnessing at the same time as the routine tests. For all tests which require full load, use 1.0 power factor unless otherwise noted. For all tests that are "not already on file", connect loads to the converter with an aircraft power cable assembly, 105 feet long, similar to the specified project aircraft power cable assembly. Monitor and record all data at the load end of the cable, unless otherwise noted. The tests conducted on the unit must include the following:

- a. Initial Safety Verification: Perform tests and checks to validate the safe and timely shutdown for each condition (for the power source and the output cable) identified in paragraph SAFETY FUNCTIONS.
- b. Surge protection: Apply input surges in accordance with IEEE C62.41.1 and IEEE C62.41.2, Location Category B and monitor output. Conduct a minimum of three consecutive successful tests on each unit listed. Confirm there is no interruption to 400 Hz output power and voltage stays within specified regulation tolerances. Surge protection tests must be applicable on all frequency converter units utilizing same surge protection device by manufacturer and part number regardless of frequency converter kW size.
- c. Input current: Perform the following tests at nominal input voltage. Conduct each test a minimum of three times. Monitor the input and output power to demonstrate the duration of the transients until the converter reaches steady state. Provide copies of waveforms and analysis in test report.

- (1) Measure inrush current when initially turning on machine with no load.
- (2) After applying power and unit is at steady state, conduct load application test, going from 0 to full load to measure affect on input.
- d. Input current distortion: Operate at nominal input voltage at 0, 25, 50, 75, and 100 percent of rated full load. Measure and record the input current THD for the current in each phase.
- e. Overload: Operate at nominal input voltage and output voltage with loads as listed below:

<u>Percent of Full Load</u>	<u>Satisfactory Operating Time</u>	<u>Time Between Overloads</u>	<u>Iterations</u>
110 percent	60 minutes	4 hours	3
125 percent	5 minutes	10 minutes	3
150 percent	2 minutes	10 minutes	3
200 percent	20 seconds	5 minutes	3

Monitor output to confirm there is no 400 Hz power interruption. After minimum operating time is achieved, unit must interrupt output power. Provide voltage and current waveforms documenting the unit's response for each test.

- f. Short-circuit: Apply a bolted line-to-line fault and a bolted three phase fault directly to the output terminals of the unit. Conduct a minimum of three consecutive successful tests on each unit. Provide unit capable of carrying the fault current until the integral system protective devices interrupts the fault with no damage to the unit. Provide waveforms of short circuit current during short circuit tests.
- g. Output voltage THD: Operate at nominal input voltage at full load with balanced and 15 percent unbalanced load. A 15 percent unbalanced load is defined as follows:

- (1) Phase A at full rated single phase load.
- (2) Phase B at 85 percent of Phase A
- (3) Phase C at 85 percent of Phase A

Measure and record the output voltage THD for the line-to-neutral voltage of each phase.

- h. Phase angle regulation: Operate at full load with balanced and 15 percent unbalanced loads. Measure and record output voltage and current, and identify RMS phase voltages and displacement angles between adjacent output voltage phases. A 15 percent unbalanced load is defined as follows:
 - (1) Phase A at full rated single phase load.
 - (2) Phase B at 85 percent of Phase A.

(3) Phase C at 85 percent of Phase A.

- i. Transient recovery: Operate at the following load steps: 0 to 100 percent, 0 to 50 percent, 100 to 0 percent and 50 to 0 percent. Measure and record recovery time and output voltage deviation limits. Provide recordings or display of output voltage during transient recovery test.

2.6 ARC FLASH WARNING LABEL

Provide arc flash warning labels for arc flash protection in accordance with NFPA 70E and NEMA Z535.4 for the enclosures of electrical equipment that are likely to require examination, adjustment, servicing, or maintenance while energized. Locate this self-adhesive warning label on the outside of the equipment compartment doors warning of potential electrical arc flash hazards and appropriate PPE required. Provide label format as indicated. The marking must be clearly visible to everyone, including qualified persons, before examination, adjustment, servicing, or maintenance of the equipment.

2.7 FIELD FABRICATED NAMEPLATES

ASTM D709. Provide laminated plastic nameplates for each equipment enclosure, relay, switch, and device; as specified or as indicated on the drawings. Each nameplate inscription must identify the function and, when applicable, the position. Nameplates must be melamine plastic, 0.125 inch thick, white with black center core. Surface must be matte finish. Corners must be square. Accurately align lettering and engrave into the core. Minimum size of nameplates must be 1 by 2.5 inches. Lettering must be a minimum of 0.25 inch high normal block style.

2.8 GROUNDING AND BONDING

UL 467. Provide grounding and bonding as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

PART 3 EXECUTION

3.1 INSTALLATION

Install products to operate at 400 Hz in the same manner as specified in other sections of this specification for products operating at 60 Hz, unless indicated or specified otherwise. Conform to the requirements of NFPA 70 and IEEE C2 and to manufacturer's instructions and recommendations.

3.2 EQUIPMENT

3.2.1 Floor Mounted

Provide proper floor mounting channels and install in accordance with the manufacturer's drawings and instructions and as indicated. Align, level, and bolt units to channels to allow easy withdrawal or insertion of removable components and to permit proper operation and maintenance of equipment. When in a Class 1, Division 2 area, mount units at least 18 inches above finished floor.

3.2.2 Grounding and Bonding

In accordance with NFPA 70 and as specified in Section 26 20 00 INTERIOR

DISTRIBUTION SYSTEM.

3.2.3 Foundation for Equipment and Assemblies

Mount equipment on concrete slab as follows:

- a. Unless otherwise indicated, provide the slab with dimensions at least 8 inches thick, reinforced with a 6 by 6 inches - W2.9 by W2.9 mesh placed uniformly 4 inches from the top of the slab.
- b. Place slab on a 6 inch thick, well-compacted gravel base.
- c. Install slab such that top of concrete slab is approximately 4 inches above the finished grade with gradual slope for drainage.
- d. Provide edges above grade with 1/2 inch chamfer.
- e. Provide slab of adequate size to project at least 8 inches beyond the equipment.

Stub up conduits, with bushings, 2 inches into cable wells in the concrete pad. Coordinate dimensions of cable wells with equipment cable training areas.

3.2.3.1 Cast-In-Place Concrete

Provide cast-in-place concrete work in accordance with the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE.

3.2.4 Wiring and Conduit

Provide wiring and conduit as specified in Section 26 20 00, INTERIOR DISTRIBUTION SYSTEM. Use copper conductors type XHHW, 7-conductor, 6 around 1, twisted for 400 Hz systems. Use aluminum conduit for exposed 400 Hz feeders. Do not install aluminum conduit underground or encased in concrete. Use aluminum fittings and boxes with aluminum conduit. Use PVC conduit and fittings for underground or concrete encased 400 Hz feeders.

3.2.5 Manufacturer's Representative

The manufacturer's representative must place the system in operation and make necessary adjustments to ensure optimum operation of the equipment. The manufacturer's representative must have at least 2 years of practical experience in the installation and testing of 400 Hz solid state frequency converters.

3.3 FIELD FABRICATED NAMEPLATE MOUNTING

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

3.4 WARNING SIGN MOUNTING

Provide the number of signs required to be readable from each accessible side. Space the signs in accordance with NFPA 70E.

3.5 FIELD APPLIED PAINTING

Where field painting of enclosures is required to correct damage to the manufacturer's factory applied coatings, provide manufacturer's recommended coatings and apply in accordance to manufacturer's instructions.

3.6 FIELD QUALITY CONTROL

3.6.1 Field Test Schedule

Give Contracting Officer 30 days notice of dates, times and scheduled tests which require the presence of the Contracting Officer. The Contracting Officer will coordinate with the using activity and schedule a time that will eliminate or minimize interruptions and interference with the activity operations.

3.6.2 Instruments

Provide test instruments capable of measuring and recording or displaying test data at a higher resolution and greater accuracy than specified for the converter's performance. The test instruments used in the field tests must have current valid calibration stickers issued by an approved calibration laboratory. Verify calibration and adjustments of converter instruments provided prior to field tests. Calibrate instruments for 400 Hz operation when measuring 400 Hz signals.

3.6.3 Initial Inspection and Tests

Perform in accordance with the manufacturer's recommendations and include the following visual and mechanical inspections and electrical tests.

- a. Compare equipment nameplate information with specifications and approved shop drawings.
- b. Inspect physical and mechanical condition. Inspect cables and wiring harnesses for damage and strain relief.
- c. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey. Perform thermographic survey while the unit is at full load during the loadbank test.
- d. Perform specific inspections and mechanical tests as recommended by manufacturer.
- e. Verify correct equipment grounding.

3.6.4 Field Performance Checks and Tests

Conduct converter field checks and tests under the supervision of the manufacturer's representative. Provide labor, equipment, test instruments, and incidentals required for the tests including resistive load banks, except the Government will furnish the electricity. For all electrical load tests, use 1.0 power factor unless otherwise noted.

All tests must be performed with the load connected to the load end of the specified aircraft cable assembly. The cable must be laid out / uncoiled

to provide heat dissipation. No adjustment to the converter is allowed between tests. Successfully complete the safety verification, preliminary operation, and the control and protective devices check prior to performing load and transient tests. Load tests must be performed with the converter doors closed. If the converter fails to operate within the specified limits during any of the tests, discontinue the test, make necessary repairs to correct the failure, and restart testing of the converter. Repeat all previously completed tests and document the respective failed test data and new data.

3.6.4.1 Initial Safety Verification

Perform tests and checks to validate the safe and timely shutdown for each condition (for the power source and the output cable) identified in paragraph SAFETY FUNCTIONS. As an exception, a representative fault test will be sufficient at this time.

3.6.4.2 Preliminary Operation

Inspect the converter and make adjustments necessary to assure proper operation in accordance with the manufacturer's instructions. Operate converter at 0, 25, 50, 75, and 100 percent of rated full load. On both the input and the output, measure and record the voltage, current, frequency, and THDs (voltage and current) at each load. Calculate output voltage regulation. Verify converter is operating within specified limits at each load level.

Test data must include voltage and current harmonic distortion amplitudes of all individual harmonics presented in a spectrum analysis format up to the 15th order at the 50 percent and 100 percent load points.

3.6.4.3 Control and Protective Device Checks

Operate each control, switch, input/output device that is capable of being operated manually a minimum of three times, demonstrating satisfactory operation each time. Perform operation test on each protective device to ensure that devices function properly. After each operation measure and record the converter output frequency, voltage and current. Verify converter is operating within specified limits.

3.6.4.4 Load (Burn-in) Test

Operate each unit continuously a minimum of 1 hour at 100 percent rated full load. Measure and record the converter output frequency, voltage and current at beginning, 30 minutes, and 1 hour. Verify converter is operating within specified limits. Load test must be performed with the converter doors closed and the test load connected to the converter at the cable head with specified aircraft cable assembly.

3.6.4.5 Post Load Test Verification

Repeat tests identified in paragraph PRELIMINARY OPERATION, to validate converter was not affected by the Load test. However apply loads in the reverse order (e.g. 100, 75, 50, 25, and 0 percent of the rated full load).

Conduct tests on each converter with the load connected to the load end of the specified aircraft power cable assembly. No adjustment to the converter is allowed between load tests. Monitor and record output voltage at the load end of the cable. Verify specified performance of the

converter including the line drop compensation.

3.6.4.6 Final Safety Verification

Repeat tests conducted under paragraph INITIAL SAFETY VERIFICATION to confirm safety features were not affected by previous tests.

3.6.5 Grounding System

Inspect grounding system for compliance with contract plans and specifications.

3.7 DEMONSTRATION

3.7.1 Instructing Government Personnel

Provide field training to Government personnel on the operation and maintenance of the converter provided at the same time as the Field Acceptance Testing. Include up to a maximum of 2 hours of instruction on operation and up to a maximum of 4 hours of repair and maintenance of the converters. The instructor must be approved by the manufacturer of the unit provided. Submit training syllabus including each topic of training and a brief outline of each topic to the Contracting Officer at least 4 weeks prior to training for approval.

Training must be approved by the Contracting Officer at least 2 weeks in advance. The Government may record, video and audio, the training sessions and use these recordings to train personnel on the operation and maintenance of the converter system. Provide two copies of video or audio DVDs, and of any supplemental information and examples covered in the training sessions, to the Contracting Officer.

-- End of Section --

SECTION 26 41 00

LIGHTNING PROTECTION SYSTEM
08/23

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 81 (2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code

NFPA 780 (2023) Standard for the Installation of Lightning Protection Systems

U.S. AIR FORCE (USAF)

DAFMAN 32-1065 (2020) Grounding and Electrical Systems

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-575-01 (2012; with Change 1, 2021) Lightning and Static Electricity Protection Systems

UNDERWRITERS LABORATORIES (UL)

UL 96 (2016; May 2023) UL Standard for Safety Lightning Protection Components

UL 96A (2023) UL Standard for Safety Installation Requirements for Lightning Protection Systems

UL 1449 (2021; Reprint Dec 2022) UL Standard for Safety Surge Protective Devices

UL Electrical Construction (2012) Electrical Construction Equipment Directory

1.2 RELATED REQUIREMENTS

1.2.1 Verification of Dimensions

Confirm all details of work, verify all dimensions in field, and advise Contracting Officer of any discrepancy before performing work. Obtain prior approval of Contracting Officer after engineering approval and

before making any departures from the design.

1.2.2 System Requirements

Provide a system furnished under this specification consisting of the latest products of a manufacturer regularly engaged in production of lightning protection system components. Products must be UL listed for use on lightning protection systems unless this rating does not exist for items in question.

Comply with NFPA 70, NFPA 780, UL 96, and UFC 3-575-01.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-06 Test Reports

Lightning Protection and Grounding System Test Plan; G

Grounding Systems Testing; G

SD-07 Certificates

Component UL Listed and Labeled; G

Lightning Protection System Inspection Certificate; G

Roof Manufacturer's Warranty; G

1.4 QUALITY ASSURANCE

In each standard referred to herein, consider the advisory provisions to be mandatory, as though the word "shall" or "must" has been substituted for "should," wherever it appears. Interpret references that require LPS expertise in these standards to mean Base Civil Engineer (BCE) or BCE-designated representative with LPS training certification.

1.4.1 Component UL Listed and Labeled

Submit proof of compliance that components are UL Listed and Labeled for use on lightning protection systems. Listing alone in UL Electrical Construction, which is the UL Electrical Construction Directory, is not acceptable evidence. In lieu of Listed and Labeled, submit written certificate from an approved, nationally-recognized testing organization equipped to perform such services, stating that items have been tested and conform to requirements and testing methods of Underwriters Laboratories (UL).

1.4.2 Lightning Protection and Grounding System Test Plan

Provide lightning protection system and grounding system test plans in compliance with NFPA 780. Identify (by number or letter, at the preference of the base - 1.2.3. or a.b.c.) the system test

points/locations along with a listing or description of the item to be tested and the type of test to be conducted. As a minimum, include a sketch of the facility and surrounding lightning protection system as part of the specific test plan for each structure. Include the requirements as "Testing of Integral Lightning Protection System" in the test plan. For explosives facilities, the rolling sphere must be superimposed in elevation drawings, on all three of these types of lightning protection systems for installations with a high strike density as indicated in the NOAA Strike Density Maps. This may be accomplished by Computer Aided Design (CAD). Integral systems are discouraged on explosives and communications facilities because it has the potential to bring lightning closer to what is being protected. For explosives facilities, record drawings with materials description (wire size, air terminal material, etc.) is required by the base Weapons Safety Office. Testing of Surge Protective Devices must comply with UL 1449 and annual inspection of Surge Protective Devices should be included on Figures A7.6 and A7.7.

1.4.3 Lightning Protection System Inspection Certificate of Qualifications

Provide an approved third-party inspector who meets training certification requirements for final acceptance of the LPS. Inspection and certification of the LPS must be completed and certified in writing, before occupancy of the building. Compliance requirements are in UFC 3-575-01. Signed Certificate of Qualifications must be placed in the LPS records.

Note that the Contracting Officer may not accept the LPS system without a recommendation from a qualified person identified in the project documents.

1.5 SITE CONDITIONS

Confirm all details of work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before starting any work, if known at that time, or when it becomes known while performing work. Obtain prior approval of the BCE or BCE-designated representative with LPS training certification before design changes are made.

PART 2 PRODUCTS

2.1 MATERIALS

See NFPA 70, NFPA 780, UFC 3-575-01. Do not use a combination of materials that forms an electrolytic couple of such nature that corrosion is accelerated in the presence of moisture unless moisture is permanently excluded from the junction of such metals. Where unusual conditions exist which would cause corrosion of conductors, provide conductors with protective coatings, such as tin or lead, or oversize conductors. Where a mechanical hazard is involved, increase conductor size to compensate for the hazard or protect conductors. When metallic conduit or tubing is provided, electrically bond conductor to conduit or tubing at the upper and lower ends by clamp type connectors or welds (including exothermic). All lightning protection components, such as bonding plates, air terminals, air terminal supports and braces, chimney bands, clips, connector fittings, and fasteners are to comply with the requirements of UL 96 classes, as applicable.

2.1.1 Main and Bonding Conductors

Main and Bonding Conductors should be NFPA 780 and UL 96 Class I or Class

II materials, as applicable. For explosives, Class II materials are in accordance with NFPA 780, Chapter 8.

2.1.2 Conductors

Provide copper or aluminum conductors, as applicable. See NFPA 780, UFC 3-575-01.

2.2 COMPONENTS

2.2.1 Air Terminals on Integral Systems

Provide solid air terminals. Tubular air terminals are not permitted. Support air terminals more than 24 inches in length by suitable brace, supported at not less than one-half the height of the terminal.

2.2.2 Ground Rods

Provide ground rods conforming to NFPA 780. Provide ground rods that are not less than 5/8 inch in diameter and 8 feet in length. Do not mix ground rods of copper-clad steel and solid copper on the job.

2.2.3 Connections and Terminations

Provide connectors for splicing conductors that conform to UL 96, class as applicable. Conductor connections can be made by compression clamps or welds (including exothermic). Provide style and size connectors required for the installation.

2.2.4 Connector Fittings

Provide connector fittings for "end-to-end", "Tee", or "Y" splices that conform to NFPA 780 and UL 96.

PART 3 EXECUTION

3.1 LIGHTNING PROTECTION SYSTEMS

Provide a lightning protection system that meets the requirements of NFPA 780 and UFC 3-575-01.

3.1.1 Integral Lightning Protection System

The integral type lightning protection system consists of air terminals, roof conductors, down conductors, ground connections, grounding electrodes and ground ring electrode conductor for the purpose of carrying lightning current from a direct strike to ground in a manner that will protect assets and personnel. Expose all conductors on the structures except where exterior down conductors are required to be in protective sleeves for prevention of mechanical damage (6 feet above grade level). Integral systems are the least preferred, especially for explosives and communications facilities. When use of integral systems is determined by the designer or site conditions to be necessary, do not run down conductors inside columns or other methods which will prevent visual access for required inspections. Visual access is required by NFPA 780 so that the annual visual inspection may be performed on all LPS components.

Make interconnections within side-flash distances between down conductors and metallic equipment mounted on the exterior or interior of a facility,

at or below the level of the grounded metallic parts. Calculate side-flash distances in accordance with NFPA 780. Be aware of side flashes that may occur through exterior walls.

Note that integral systems should be avoided as LPS for Explosives and Communications facilities and is discouraged for general facilities. Installation and maintenance costs of an integral system are excessive and this method is maintenance intensive. The complexity and number of test points dictates frequent interruption to missions and daily operations for required annual inspections and testing. Integral systems require fall protection and maintenance of that fall protection system. For fall protection, maintain NFPA 780-compliant separation distance between the integral system and metallic fall protection.

3.1.1.1 Roof-Mounted Components

Coordinate with the roofing manufacturer and provide certification that the roof manufacturer's warranty is not violated by the installation methods for air terminals and roof conductors. Adhesive fasteners may be used on the roof if the installation is observed by base-qualified personnel to be compliant with manufacturer's instructions. Installation must be observed until the observer is satisfied that the proper methods for preparing the surface are being performed. These fasteners will be added and considered a test point in Base records and must be part of the annual inspection. Observer must date and sign the test record.

No connection or physical attachment is allowed to any coping system on the roof as this violates the integrity and warranty of the coping system.

3.1.1.2 Air Terminals

Use of adhesive fasteners, when installing air terminals on "rubber" (EPDM) type roofs, should be in accordance with adhesive and roof manufactures' recommendations. See paragraph ROOF-MOUNTED COMPONENTS.

3.1.1.3 Roof Conductors

Roof conductors should comply with NFPA 780.

3.1.2 Down Conductors

A minimum of two paths to ground shall be provided on any system. This may be by two down conductors or with a down conductor in combination with other metallic connections to ground. Protect exposed down conductors from physical damage from ground level up to 6 feet. If this protection is a metal conduit, both ends must be bonded to the down conductor passing through it. For Schedule 80 conduit providing this protection, no bonding at both ends is necessary. Schedule 80 conduit or metallic conduit may be painted to match the surrounding surface. NO CONNECTIONS OR FASTENERS OF ANY LIGHTNING PROTECTION SYSTEM MAY BE PAINTED because this affects the ease with which lightning current can pass to ground.

3.1.3 Ground Connections

Attach each down conductor and ground ring electrode to a ground rod below grade by exothermic weld for all buried connections and exothermic weld or compression connectors for connections inside test wells. Terminate all down conductors to a grounding electrode inside a test well. Test connections and record resistances and continuity readings prior to

covering.

Accessible connections above ground level and in test wells can be grounded with mechanical clamping, meeting installation requirements in NFPA 780.

3.1.4 Installation of Grounding Electrodes (Ground Rods)

Extend driven ground rods vertically into the existing undisturbed earth for a distance of not-less-than 8 feet if exothermic welds are used for bonds. Inside test wells, the 5/8 in. by 8 ft rod may be driven to a point above the base of the test well, that will provide working/testing access to the mechanically-fastened bond. Set ground rods not less than 3 feet nor more than 6 feet (see NFPA 780) from the structural foundation, and at least 3 feet beyond the drip line for the facility. After the completed installation, measure the total resistance to ground using the fall-of-potential method described in IEEE 81. Maximum allowed resistance of a single driven ground rod is 25 ohms (NFPA 70). If resistance-to-ground of a single ground rod for the lightning protection system exceeds 25 ohms and another ground rod is driven in accordance with NFPA 780, 25 ohms does not apply to this test point. See NFPA 70 exception to Article 250.53.

3.2 APPLICATIONS

3.2.1 Personnel Ramps and Covered Passageways

Lightning Protection is required in accordance with NFPA 780 and UFC 3-575-01.

3.3 INTERFACE WITH OTHER STRUCTURES

3.3.1 Fences

Bond metal fence and gate systems to the lightning protection system at the point where the fence, any fence post, or gate is within 6 feet of any part of the lightning protection system (usually a down conductor) in accordance with ANSI C2 and NFPA 780 and UFC 3-575-01.

3.4 RESTORATION

Where sod has been removed, replace sod as soon as possible after completing the backfilling. Restore areas disturbed by trenching, storing of dirt, cable laying, and other work, to original condition. Overfill the trench to accommodate for settling. Include necessary topsoil, fertilizing, liming, seeding, sodding, sprigging or mulching in any restoration, to match existing. Maintain disturbed surfaces and replacements until final acceptance. Return to site after six months to fill in compacted surface.

3.5 FIELD QUALITY CONTROL

3.5.1 Lightning Protection Systems Testing

A 100 percent test point test and inspection is required by all services. Identify test points for lightning protection system connections and bonds. Provide a sketch (NTS) with identified test points as part of the contract acceptance. Number points in a manner consistent with the installation (Base or Post) nomenclature for existing lightning protection

systems; for example, use letters or numbers to track the test results. Test each lightning protection system connection to ensure continuity across each connection or bond is 1 ohm or less, and record the value indicated on a copy of the test form located at the back of DAFMAN 32-1065, Attachment 7.

- a. LPS testing must also be accomplished on smaller projects, such as roofing and HVAC projects, where lightning protection systems are installed on any facility with existing LPS, to ensure the LPS is not damaged or reconfigured during construction.
- b. Comply with UL 96A. A third-party inspector (not the designer and not the installer) must be present for the 100 percent inspection and data documentation by the contractor. This is to take place prior to project acceptance. Note that in many cases Air Force personnel have been trained to inspect and accept projects as the third-party inspector. Verify this before contract award.

3.5.2 Grounding Systems Testing

A 100 percent test point resistance test and inspection is required. Identify all test points for grounding system connections and bonds. Provide a sketch (NTS) with identified test points as part of the contract acceptance. Number points in a manner consistent with the installation (Base or Post) nomenclature for existing grounding systems; for example, use letters or numbers to track the test results. Test each grounding system connection or bond to ensure resistance-to-ground is 25 ohms or less or as excepted by NFPA 70 or NFPA 780. Record the resistance measurement on a copy of the test form located at the back of DAFMAN 32-1065 for Air Force or a similar form provided by the Army or Navy. Test the ground rod for resistance to ground before making connections to the rod. Tie the grounding system together and test for resistance to ground. Make resistance measurements in dry weather, and not earlier than 48 hours after rainfall. Include in the written report: locations of test points, measured values for continuity and ground resistances, and soil conditions at the time that measurements were made. Submit results of each test to the Contracting Officer.

-- End of Section --

SECTION 26 42 13

GALVANIC (SACRIFICIAL) ANODE CATHODIC PROTECTION (GACP) SYSTEM
05/21

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B1.1	(2003; R 2018) Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B1.20.1	(2013; R 2018) Pipe Threads, General Purpose (Inch)
ASME B16.5	(2020) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.21	(2021) Nonmetallic Flat Gaskets for Pipe Flanges
ASME B16.39	(2020) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300
ASME B18.2.1	(2012; Errata 2013) Square and Hex Bolts and Screws (Inch Series)
ASME B18.2.2	(2022) Nuts for General Applications: Machine Screw Nuts, and Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)

ASTM INTERNATIONAL (ASTM)

ASTM A194/A194M	(2023) Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM A307	(2021) Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength
ASTM B3	(2013) Standard Specification for Soft or Annealed Copper Wire
ASTM B8	(2023) Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

ASTM B418	(2016a; R2021) Standard Specification for Cast and Wrought Galvanic Zinc Anodes
ASTM B843	(2018) Standard Specification for Magnesium Alloy Anodes for Cathodic Protection
ASTM C94/C94M	(2023) Standard Specification for Ready-Mixed Concrete
ASTM D709	(2017) Standard Specification for Laminated Thermosetting Materials
ASTM D1248	(2016) Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
ASTM D2028/D2028M	(2015; R 2021) Cutback Asphalt (Rapid-Curing Type)
ASTM D3381/D3381M	(2018) Standard Specification for Viscosity-Graded Asphalt Binder for Use in Pavement Construction

NACE INTERNATIONAL (NACE)

NACE SP0106	(2018) Control of Internal Corrosion in Steel Pipelines and Piping Systems
NACE SP0177	(2019) Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems
NACE SP0188	(2024) Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates
NACE SP0286	(1997; R 2007) Standard Practice Electrical Isolation of Cathodically Protected Pipelines
NACE SP21424	(2018) Alternating Current Corrosion on Cathodically Protected Pipelines: Risk Assessment, Mitigation and Monitoring
NACE TPC 11	(2008) A Guide to the Organization of Underground Corrosion-Control Coordinating Committees

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C119.1	(2023) Electric Connectors - Sealed Insulated Underground Connector Systems Rated 600 Volts
NEMA ICS 6	(1993; R 2016) Industrial Control and Systems: Enclosures

NEMA RN 1 (2005; R 2013) Polyvinyl-Chloride (PVC)
Externally Coated Galvanized Rigid Steel
Conduit and Intermediate Metal Conduit

NEMA TC 2 (2020) Standard for Electrical Polyvinyl
Chloride (PVC) Conduit

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National
Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-A-18001 (1993) Anodes, Sacrificial Zinc Alloy

MIL-I-1361 (1985; Rev C; Notice 1 1991; Notice 2
2021) Instrument Auxiliaries, Electrical
Measuring: Shunts, Resistors and
Transformers

UNDERWRITERS LABORATORIES (UL)

UL 6 (2022) UL Standard for Safety Electrical
Rigid Metal Conduit-Steel

UL 83 (2017; Reprint Mar 2020) UL Standard for
Safety Thermoplastic-Insulated Wires and
Cables

UL 510 (2020; Dec 2022) UL Standard for Safety
Polyvinyl Chloride, Polyethylene and
Rubber Insulating Tape

UL 514A (2013; Reprint Jun 2022) UL Standard for
Safety Metallic Outlet Boxes

UL 514B (2012; Reprint Mar 2024) UL Standard for
Safety Conduit, Tubing and Cable Fittings

1.2 DEFINITIONS

It is convenient to classify corrosion by the forms in which it manifests itself, the basis for this classification being the appearance of the corroded metal. Each form can be identified by visual observation, although, in some cases, magnification is required. Valuable information for the solution of a corrosion problem can often be obtained through careful observation of the corroded test specimens or failed equipment. Examination before cleaning is particularly desirable. Cathodic Protection is a method used to control corrosion.

1.2.1 Cathodic Protection

Cathodic Protection (CP) is an electrochemical (half electrical and half chemical) method used to control corrosion of buried or submerged metallic structures. It prevents corrosion by making the protected structure a cathode by installing a more anodic metal (sacrificial or galvanic) anode or a metallic (impressed current) anode connected to a Direct Current (DC) power source. When the proper amount of current is applied to the

structure, it becomes a cathode. Since all corrosion occurs at the anode, the structure no longer corrodes. The electrons move in the metallic path (electrical). Reduction (chemical) reactions occur at the surface of the cathode resulting in a hydrogen coating and more alkaline environment. Oxidation (chemical) reactions occur at the surface of the anode resulting in corrosion and a more acidic environment. After a CP system is installed and adjusted to provide adequate protection, the hydrogen coats the defects in the coating and polarizes in the negative direction (to a copper/copper sulfate reference electrode) over time the current and potentials remain relatively stable; changes in currents or potentials indicate a problem. An error-free measurement of negative 850 millivolts DC or more negative to the copper/copper-sulfate reference electrode proves the structure is a cathode and corrosion has been mitigated.

1.2.2 Corrosion

It is convenient to classify corrosion by the forms in which it manifests itself, the basis for this classification being the appearance of the corroded metal. Each form can be identified by visual observation, although, in some cases, magnification is required. Valuable information for the solution of a corrosion problem can often be obtained through careful observation of the corroded test specimens or failed equipment. Examination before cleaning is particularly desirable. Some of the eight forms of corrosion are unique, but all of them are more or less interrelated.

The eight forms of corrosion are: (1) Uniform Attack, (2) Galvanic or Two-Metal Corrosion, (3) Crevice Corrosion, (4) Pitting Corrosion, (5) Intergranular Corrosion, (6) Selective Leaching, (7) Erosion Corrosion, and (8) Stress Corrosion Cracking. This listing is arbitrary but covers practically all corrosion failures and problems. The forms are not listed in any particular order of importance. Below, the eight forms of corrosion are discussed in terms of their characteristics, mechanisms, and preventive measures. Hydrogen damage, although not a form of corrosion, often occurs indirectly as a result of corrosive attack and is, therefore, included in this discussion.

1.2.3 Alternating Current (AC) Corrosion

AC corrosion occurs when there is a source of AC current, typically from a high voltage overhead AC (OHAC) power-line, when there is a low soil resistivity - typically less than 5,000 ohm-cm and there is a very small coating holidays. The AC corrosion pits typically have a tubercle of corrosion product at the pit. AC interference study modeling software can determine the mitigation solution to solve this problem. Typically, AC Corrosion mitigation is done in conjunction with high AC potentials and fault current mitigation.

1.2.4 AC Interference

AC interference occurs when a pipeline parallels a high-voltage overhead AC (OHAC) power-line. An interference study is required when this situation occurs as AC interference can cause high AC potentials along the pipeline (safety), can cause a fault condition between the pipeline and power-line and could cause AC corrosion to occur. The pipeline coating when exposed can have blisters/bubbles caused by the excessive AC. The interference study will use modeling software to determine what combination of interference may be occurring (if any) and provide the mitigation solution to solve the problem.

1.2.5 Uniform Attack

Uniform attack is the most common form of corrosion. It is normally characterized by a chemical or electrochemical reaction that proceeds uniformly over the entire exposed surface or over a large area. The metal becomes thinner and eventually fails. For example, a piece of steel or zinc immersed in dilute sulfuric acid normally dissolves at a uniform rate over its entire surface. A sheet iron roof shows essentially the same degree of rusting over its entire outside surface.

Uniform attack, or general overall corrosion, represents the greatest destruction of metal on a tonnage basis. This form of corrosion, however, is not of great concern from a technical standpoint, because the life of equipment can be accurately estimated on the basis of comparatively simple tests. Merely immersing specimens in the fluid involved is often sufficient. Uniform attack can be prevented or reduced by (1) materials, such as coatings, that reduce contact between metal and electrolytes, (2) inhibitors, or (3) CP.

1.2.6 Galvanic or Two-Metal Corrosion

A potential difference usually exists between two dissimilar-metals when they are immersed in a corrosive or conductive solution. If these metals are placed in contact (or otherwise electrically connected), this potential difference produces electron flow between them. Corrosion of the less corrosion-resistant metal is usually increased, and attack of the more resistant material is decreased, compared to the behavior of these metals when they are not in contact. The less resistant metal becomes anodic and the more resistant metal becomes cathodic. Usually the cathode or cathodic metal corrodes very little or not at all in this type of couple. Because of the electric currents and dissimilar-metals involved, this form of corrosion is called galvanic, bi-metallic or two-metal, corrosion. Galvanic corrosion is restricted to electrochemical corrosion caused by dissimilar-metal effects. It is electrochemical corrosion, but this document must restrict the term galvanic to dissimilar-metal effects for purposes of clarity.

1.2.7 Crevice Corrosion

Intense localized corrosion frequently occurs within crevices and other shielded areas on metal surfaces exposed to corrosives. This type of attack is usually associated with small volumes of stagnant solution caused by holes, gasket surfaces, lap joints, surface deposits, and crevices under bolt and rivet heads. As a result, this form of corrosion is called crevice corrosion or, sometimes, deposit or gasket corrosion.

1.2.8 Pitting Corrosion

Pitting is a form of extremely localized attack that results in holes in the metal. These holes may be small or large in diameter, but in most cases they are relatively small. Pits are sometimes isolated or so close together that they look like a rough surface. Generally a pit may be described as a cavity or hole with the surface diameter about the same as or less than the depth. Pitting is one of the most destructive and insidious forms of corrosion. It causes equipment to fail because of perforation with only a small percent weight loss of the entire structure. It is often difficult to detect pits because of their small size and because the pits are often covered with corrosion products. In

addition, it is difficult to measure quantitatively and compare the extent of pitting because of the varying depths and numbers of pits that may occur under identical conditions. Pitting is also difficult to predict by laboratory tests. Sometimes the pits require a long time (several months or a year) to show up in actual service. Pitting is particularly vicious because it is a localized and intense form of corrosion, and failures often occur with extreme suddenness.

1.2.9 Intergranular Corrosion

Grain boundary effects are of little or no consequence in most applications or uses of metals. If a metal corrodes, uniform attack results since grain boundaries are usually only slightly more reactive than the matrix. However, under certain conditions, grain interfaces are very reactive and intergranular corrosion results. Localized attack at and adjacent to grain boundaries, with relatively little corrosion of the grains, is intergranular corrosion. The alloy disintegrates (grains fall out) or loses its strength. Intergranular corrosion can be caused by impurities at the grain boundaries, enrichment of one of the alloying elements, or depletion of one of these elements in the grain-boundary areas. Small amounts of iron in aluminum, wherein the solubility of iron is low, have been shown to segregate in the grain boundaries and cause intergranular corrosion. It has been shown that, based on surface tension considerations, the zinc content of a brass is higher at the grain boundaries. Depletion of chromium in the grain-boundary regions results in intergranular corrosion of stainless steels.

1.2.10 Selective Leaching

Selective leaching is the removal of one element from a solid alloy by corrosion processes. The most common example is the selective removal of zinc in brass alloys (dezincification). Similar processes occur in other alloy systems in which aluminum, iron, cobalt, chromium, and other elements are removed. Selective leaching is the general term to describe these processes, and its use precludes the creation of terms such as de-aluminumification, de-cobaltification. Parting is a metallurgical term that is sometimes applied, but selective leaching is preferred.

1.2.11 Erosion Corrosion

Erosion corrosion is the acceleration or increase in rate of deterioration or attack on a metal because of relative movement between a corrosive fluid and the metal surface. Generally, this movement is quite rapid, and mechanical wear effects or abrasion are involved. Metal is removed from the surface as dissolved ions, or it forms solid corrosion products, which are mechanically swept from the metal surface. Sometimes, movement of the environment decreases corrosion, particularly when localized attack occurs under stagnant conditions; this is not erosion corrosion because deterioration is not increased. Erosion corrosion is characterized in appearance by grooves, gullies, waves, rounded holes, and valleys and usually exhibits a directional pattern. In many cases, failures because of erosion corrosion occur in a relatively short time, and they are unexpected largely because evaluation corrosion tests were run under static conditions or because the erosion effects were not considered.

1.2.12 Stress-Corrosion Cracking

Stress-corrosion cracking refers to cracking caused by the simultaneous presence of tensile stress and a specific corrosive medium. Many

investigators have classified all cracking failures occurring in corrosive media as stress-corrosion cracking, including failures due to hydrogen embrittlement. However, these two types of cracking failures respond differently to environmental variables. To illustrate, CP is an effective method for preventing stress-corrosion cracking; however, hydrogen-embrittlement may be caused when excessive current is applied, especially on stainless steel. Hence, the importance of considering stress-corrosion cracking and hydrogen embrittlement as separate phenomena is obvious. During stress-corrosion cracking, the metal or alloy is virtually unattacked over most of its surface, while fine cracks progress through it. This cracking phenomenon has serious consequences, since it can occur at stresses within the range of typical design stress.

1.2.13 Exothermic Welding

Exothermic welding is used in CP to connect a copper wire to a metallic structure, usually steel or cast-iron. It is a pyrotechnic composition of copper oxide, aluminum powder and magnesium powder. The magnesium powder is ignited with a spark gun or electronic ignition equipment. The aluminum powder serves as fuel, and melts the copper oxide, which bonds the wire to the structure. Although not explosive, it can create brief bursts of heat and high temperature in a small area.

1.2.14 Error-Free

Potential measurement error due to a voltage drop caused by current flowing through a resistor (the electrolyte) between the reference electrode and the protected structure.

1.3 ADMINISTRATIVE REQUIREMENTS

After award of the contract, but prior to commencement of any work at the site, meet with the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Develop a mutual understanding relative to the administration of the value engineering, the safety program, preparation of the schedule of prices or the earned value report. Review shop drawings, and other submittals, scheduling programming, execution of the work, and clear expectations of the "Interim Department of Defense (DD) Form 1354" submittal. Major subcontractors who will engage in the work must also attend.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability Notebook, in conformance to 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Preconstruction Survey

SD-02 Shop Drawings

Drawings; G

Isolation flange kits

Anode junction boxes, bonding boxes, and test stations

Joint bonds

Contractor's Modifications; G

SD-03 Product Data

Qualifications

Equipment; G

Anodes; G

Anode junction boxes, bonding boxes, and test stations

Dielectric unions

Wires

Cable and wire

Casings, isolation, and seals

Shunts

Permanent reference electrodes; G

Spare Parts

SD-06 Test Reports

Tests and Measurements; G

Contractor's Modifications; G

SD-10 Operation and Maintenance Data

Cathodic Protection System; G

Training Course; G

Cathodic Protection System, Data Package 5; G

SD-11, Closeout Submittals

Initial Cathodic Protection System Field Testing; G

One Year Warranty Period Cathodic Protection System Field Test Report; G

Final Cathodic Protection System Field Test Report; G

1.4.1 Material and Equipment Manufacturer Data

DATE	ISSUE NO.	REQUEST DATE	REQUESTED BY	REQUEST REF. NO.
MANUFACTURER NAME				
DESCRIPTION OF EQUIPMENT				

1.5 MAINTENANCE MATERIAL SUBMITTALS

1.5.1 Spare Parts

After approval of shop drawings, furnish spare parts data for each different item of material and equipment specified. The data must include a complete list of parts, special tools, and supplies, with current unit prices and source of supply.

After approval of shop drawings, furnish revised spare parts for any changes made from original submittal. One spare anode of each type must be furnished. In addition, supply information for material and equipment replacement for all other components of the complete system, including anodes, cables, splice kits and connectors, corrosion test stations, and any other components not listed above. Furnish one reference electrode on a hand reel with 350 feet of conductor, one digital voltmeter that can be used in the maintenance of this CP system. Demonstrate use of furnished equipment in actual tests during the training course. Provide a description of equipment of the pipe-to-soil protected structure and foreign structures at electrical isolation between the utility supplier and the facility piping.

1.5.2 Extra Materials

Furnish one reference electrode on a hand reel with 350 feet of conductor, one high-input-impedance digital multimeter that can be used in the maintenance of this CP system. Demonstrate use of furnished equipment in actual tests during the training course. Provide a description of equipment of the pipe-to-soil protected structure and foreign structures at electrical isolation between the utility supplier and the facility piping. Include a description of the equipment and measurement of the pipe-to-soil potentials, anode voltage, anode current and soil condition.

1.6 QUALITY CONTROL

1.6.1 Regulatory Requirements

Obtain the services of a corrosion expert to supervise, inspect, and test the installation and performance of the cathodic protection system. The term "corrosion expert" refers to a person, who by thorough knowledge of the physical sciences and the principles of engineering and mathematics, acquired by professional education and related practical experience, is qualified to engage in the practice of corrosion control of buried or submerged metallic structures.

1.6.2 Qualifications

The corrosion expert must be accredited or certified by NACE International, as a CP-4 CP Specialist or be a NACE International certified Corrosion Specialist or a registered professional engineer who has certification or licensing that includes education and experience in CP of the type of CP system being installed. The corrosion expert must have not less than three years of experience in the type of CP for buried or submerged metallic structures under this contract. Submit evidence of qualifications of the corrosion expert including their name and qualifications certified in writing to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager prior to the start of construction. Certification must be submitted giving the name of the firm, the number of years of experience, and a list of not less than five of the firm's installations, three or more years old, that have been tested and found satisfactory.

1.6.3 Services of Corrosion Expert

The "corrosion expert" must make a minimum of three visits to the project site. The first of these visits will include obtaining soil resistivity data, acknowledging the type of pipeline coatings to be used and reporting to the contractor the type of CP required (GACP or ICCP). Once the submittals are approved and the materials delivered, the "corrosion expert" will revisit the site to verify the materials meet submittal requirements, ensure the contractor understands installation practices and that the contractor is capable and qualified to complete the installation.

The "corrosion expert" will be available (but not necessarily be onsite the entire time) during the installation of the CP system to answer questions, approve any changes or additions required during construction, or to provide recommendations as required. The third visit is to complete the training and demonstrations to applicable personnel on proper testing and maintenance techniques and to complete testing the installed CP systems to ensure it has been installed properly and meets adequate CP criteria. An additional visit is required if the One-Year-Warranty-Period-Testing is required.

1.7 DELIVERY, STORAGE AND HANDLING

Storage area for corrosion materials will be designated by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. If materials are not stored in a building, tarps or similar protection must be used to protect material from inclement weather. Resack and add backfill to packaged anodes that are damaged as a result of improper handling or exposure to rain.

1.8 PROJECT/SITE CONDITIONS

1.8.1 Environmental Requirements

1.8.2 Existing Conditions

Prior to start of any onsite construction activities, perform a Preconstruction Survey of the project site with the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager, and take photographs showing existing environmental conditions in and adjacent to the site. Submit a report for the record. Include in the report a plan describing the features requiring protection under the provisions of the Contract Clauses, which are not specifically identified on the drawings as environmental features requiring protection along with the condition of trees, shrubs and grassed areas immediately adjacent to the site of work and adjacent to the contractor's assigned storage area and access route(s), as applicable. The Contractor and the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager will sign this survey report upon mutual agreement regarding its accuracy and completeness. Protect those environmental features included in the survey report and any indicated on the drawings, regardless of interference that their preservation may cause to the work under the Contract.

1.9 WARRANTY

Provide equipment items that are supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

2.1.1 Corrosion Control System Description

A corrosion control system consists of several systems which work together to mitigate corrosion on buried or submerged metallic structures. Failure to comply with the requirements of any one of these systems may result in inadequate corrosion control and premature failure of the structure being protected. Each system's guide specifications must be included in the design and installation of a complete corrosion control system and must be adhered to in the design and execution of the corrosion control of a structure being protected. Determination of Need for CP must be made by government requirements and policy directives.

- a. Coating Systems (CS) are a critical factor in performance of a GACP system. All coatings, including coatings in structure guide specifications and Green Seal (GS) coatings, must be compatible with the structure and the CP system, and have high disbondment capabilities. A high resistance to cathodic disbondment is critical for long term service life of coatings on buried or submerged metallic structures under CP. For paints and coatings refer to Section 09 90 00 PAINTS AND COATINGS, and for discontinuity (Holiday) testing of new protective coatings on conductive substrates refer to NACE SP0188.

- b. Mechanical Damage Systems (MDS) such as bedding and rock control barriers normally included in Structure GS may be required by design for some locations. Electrical Isolation is required for all galvanic anode CP systems. For an Electrical Isolation System (EIS) refer to NACE SP0286.
- c. An Electrical Continuity System (ECS) of the protected structure is critical to the operation of the CP system. The types of joints such as bonding and couplings are normally included in Structure GS, this is particularly important to nonwelded pipelines to allow sufficient CP current to conduct to the entire structure.
- d. Stray Current (Interference) Systems must be considered in design, monitored during construction, and interference testing must be completed during the final testing. Design must consider all other cathodic protection systems which may affect other systems or systems which may affect the project, including foreign systems. All foreign systems must be contacted for information and notification and any joint testing which may be required. Corrosion Coordinating Committees may exist. Reference NACE TPC 11.
- e. Pipelines that parallel overhead high voltage AC transmission power systems are subject to induced AC. Induced AC has several potential adverse impacts on the safety of personnel and pipeline integrity. Assuming that these conditions exist, there are several measures that can be taken to mitigate the induced AC present on a pipeline. These induced AC mitigation strategies are detailed in various international standards including NACE SP0177.
- f. Galvanic Anode CP Monitoring System is a solution for remote monitoring (and optionally controlling) different kinds of galvanic anode CP applications, mainly to protect underground pipelines used in oil and gas distribution systems, but the same system can be used to monitor other galvanic anode CP applications like tank farms and oil platforms. These Monitoring Systems are detailed in various international standards including NACE TPC 11.
- g. When a project is connecting to an existing infrastructure with CP the design must be compatible with the existing structure(s) CP system. Existing structures may have Impressed Current CP (ICCP) Anode Systems using Remote Anode Systems, Deep Anode Systems, Linear Anode Systems, or Distributed Anode Systems. Existing structures may also have Galvanic CP (GACP) Systems which may be distributed or remote. Existing structures might not have CP. They may use alternative methods of corrosion mitigation instead of CP such as Inhibitor System/Internal Corrosion Control. For control of internal corrosion in steel pipelines and piping systems refer to NACE SP0106. Due to the limited voltage and current of galvanic anodes the protected structure must be coated and isolated from other structures.
- h. A highly dielectric bonded coating is required to attain adequate CP. Unbonded coatings block the protective current from the pipeline or structure and must not be used with CP. Failure to isolate other metallic structures will result in loss of protection. Isolation from other metallic structures must be maintained.
- i. Continuity of the structure with low resistance is crucial to proper operation of a galvanic anode system. All joints must be continuous or be bonded to both sides of the joint.

- j. A conductive electrolyte is required to allow current flow from the galvanic anodes. Use of galvanic anode systems are normally restricted to electrolytes with resistivities below 30,000 ohm-cm. Small well coated structures such as coated valves, tees and elbows have very high resistance to earth in high resistance soils. Galvanic anodes in electrolytes over 30,000 ohms also have very high resistance to earth. High circuit resistance with the low voltage of galvanic anodes will not allow sufficient current to meet instant off or depolarization criteria. Additional anodes under these conditions will not noticeably increase the current applied to the structure. Reference SP0169 for criteria in high resistance electrolytes.

2.1.2 Design Requirements

2.1.2.1 Electrical Isolators

Isolators are required to isolate the pipes from any other structure. Provide isolators at all locations where the indicated pipes contact any other metallic structure. Provide locations and detailed drawings of required installations. Include any requirements for lightning protection, test stations, surge protection, or other requirements and include locations and details in design drawings.

2.1.2.2 Anode and Bond Wires

Provide a minimum of 5 magnesium anodes with an unpackaged weight of pounds at uniform distances along the metallic pipelines. Use a minimum of 3 test stations for these anodes. Provide these anodes in addition to anodes for the pipe under concrete slab and casing requirements. For each cathodic system, provide metallic components and structures that are electrically continuous by installing bond wires between the various structures. Bonding of existing buried structures may also be required to preclude detrimental stray current effects and safety hazards. Return stray current to its source without damaging structures intercepting the stray current. Provide electrical isolation of underground facilities in accordance with acceptable industry practice. All tests must be witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager.

2.1.2.3 Surge Protection

Install approved zinc grounding cells or sealed weatherproof lightning and surge arrester devices across isolation flanges or fittings installed in underground piping as indicated on the drawings. Provide gapless, self-healing, solid state type arrester. Provide zinc anode composition conforming to ASTM B418, Type II. Provide number 4 AWG copper lead wires with High Molecular Weight Polyethylene (HMWPE) insulation. Zinc grounding cells must be prepackaged in backfill install as detailed on the drawings. Lightning arrestors or zinc grounding cells are not required for isolation flanges on metallic components used on non-metallic piping systems.

2.1.2.4 Non-metallic Pipe System

In the event pipe other than metallic pipe is approved and used in lieu of metallic pipe, protect all metallic components of this pipe system with CP. Submit detailed drawings of CP for each component to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and

Project Manager for approval within 45 days after date of receipt of notice to proceed, and before commencement of any work.

2.1.2.5 Coatings

Provide coatings for metallic components as required for metallic fittings. Complete and test protective coating on each metallic component (such as valves, hydrants and fittings). Provide coating as required for underground metallic pipe. Each test must be witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Select, apply, and inspect coatings as specified in these specifications. The use of non-metallic pipe does not change other requirements of the specifications. Submit any deviations due to the use of non-metallic pipe for approval.

2.1.2.6 Tracer Wire

When a non-metallic pipeline is used to extend or add to an existing metallic line, exothermic-weld No. 8 AWG copper wire with THHN insulation to the existing metallic line and run the length of the new non-metallic line. Use this wire as a locator tracer wire and to maintain continuity to any future extensions of the pipeline.

2.1.2.7 Drawings

Submit six copies of detail drawings consisting of a complete list of equipment and material including manufacturer's descriptive and technical literature, catalog cuts, contractor's modifications, results of system design calculations including soil-resistivity, installation instructions and certified test data showing location of anodes and stating the maximum recommended anode current output density. Include in the detail drawings complete wiring and schematic diagrams, isolation fittings, test stations, permanent reference electrodes and bonding and any other details required to demonstrate that the system has been coordinated and will function properly as a unit. Reference locations to two permanent facilities or mark points. Provide one electronic digital copy and digital photos of the completed installation.

2.1.2.8 Summary of Services Required

Include the following scope of services:

- a. Close-interval potential surveys,
- b. CP Installation System,
- c. System testing,
- d. Casing corrosion control,
- e. Interference testing,
- f. Training,
- g. Operating and maintenance manual,
- h. Isolation testing and bonding testing,
- i. Coating and holiday testing.

2.1.2.9 Tests of Components

Perform a minimum of four tests at each metallic component in the piping system. Two measurements must be made directly over the anodes and the other two tests must be over the outer edge of the component, but at the farthest point from the anodes. Provide a field drawing showing the component, the structure, all components of the CP system and their relationship to each other. Also provide a narrative describing how the CP system will work and the testing at each component. Components requiring CP must include but not be limited to the following:

- a. Pipes beneath the floor slab or foundations.
- b. Post Indicator Valve (PIV).
- c. Shutoff valves.
- d. Metallic pipes extended from aboveground locations.
- e. Connectors or change-of-direction devices.
- f. Metallic pipe components or sections.
- g. Backflow preventers.
- h. Culverts.
- i. Casings.

2.1.2.10 Electrical Potential Measurements

Make all potential tests at a minimum of 10 foot intervals witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Provide submittals identifying test locations on separate drawings, showing all metal to be protected and all CP equipment. Distinguish and identify test points, equipment, and protected metal.

2.1.2.11 Typical Metallic Components on Non-metallic Systems

2.1.2.11.1 Metallic Components

As a minimum, protect each metallic component with two galvanic anodes. This number of anodes is required to achieve minus 850 millivolts "instant off" potential on the metallic area and at the same time not provide overvoltage above 1200 millivolts "instant off." As a minimum, the galvanic anode unpackaged weight must be 9 pounds. Locate the galvanic anodes on each side of the metallic component and route through a test station.

2.1.2.11.2 Fire Hydrants

Provide fire hydrant pipe components with a minimum of two anodes. These galvanic anodes must have an unpackaged weight of pounds.

2.1.2.11.3 Pipe Beneath Concrete Slab

Pipe beneath concrete slab must have a minimum of 2 galvanic anodes.

These galvanic anodes must have an unpackaged weight of 9 pounds. Pipe beneath concrete slab must have 1 permanent reference electrodes located beneath the slab. Locate one permanent reference electrode where the pipe enters the concrete slab. Route all conductors to a test station.

2.1.2.11.4 Valves

Protect each valve with 1 galvanic anodes. The galvanic anode must have an unpackaged weight of 9 pounds.

2.1.2.11.5 Metallic Pipe Component or Section

Protect each section of metallic pipe with 2 galvanic anodes. The galvanic anodes must have an unpackaged weight of 9 pounds.

2.1.2.11.6 Connectors or Change-of-Direction Devices

Protect each change-of-direction device with 2 galvanic anodes. The galvanic anode must have an unpackaged weight of 9 pounds.

2.1.2.12 Metallic Component Coating

Coatings for metallic components will be required for metallic fittings as indicated. These metallic fittings will include fire hydrants, tees, elbows, and valves. Coatings must be selected, applied, and inspected as specified in the coating specifications referenced and be compatible with the structure being protected. All coatings must be in accordance with all applicable Federal, State, and local regulations. Unbonded coatings must not be used with CP.

2.1.2.13 Location of Test Stations

Provide test stations of the type and location shown and wall mount. Provide buried isolation joints with test wire connections brought to a test station. Reference all test stations with GPS coordinates. Unless otherwise shown, locate other test stations as follows:

- a. At 1,000-foot intervals or less.
- b. Where the pipe or conduit crosses any other metal pipe.
- c. At both ends of casings under roadways and railways.
- d. Where both sides of an isolation joint are not accessible above ground for testing purposes.

2.1.2.14 Electrical Isolation of Structures

As a minimum, provide isolating flanges or unions at the following locations:

- a. Connection of new metallic piping or components to existing piping.
- b. Pressure piping beneath floor slab to a building.

Provide isolation at metallic connection of all lines to existing system and where connecting to a building. Additionally, provide isolation between water or gas line; and foreign pipes that cross the new lines within 10 feet. Install isolation fittings, including isolating flanges

and couplings, aboveground or in a concrete pit.

2.1.2.14.1 Gas Distribution Piping

Provide electrical isolation at each building riser pipe to the pressure regulator, at all points where a short to another structure or to a foreign structure may occur, and at other locations as indicated on the drawings.

2.1.2.14.2 Isolation Joint Testing

An isolator checker or insulation tester will be used for isolation or insulating joint (flange or dielectric) electrical testing.

2.1.2.14.3 Underground Structure Coating

This coating specification takes precedence over any other project specification and drawing notes, whether stated or implied, and also applies to the pipeline or tank supplier. Variance in coating quality is not allowed by the contractor or Base Construction Representative without the written consent of the designer. All underground metallic pipelines and tanks to be cathodically protected must have a high quality factory-applied coating. This includes all carbon steel, cast-iron and ductile-iron pipelines or vessels. Select, apply, and inspect coatings as specified. If non-metallic pipelines are installed, coat all metallic fittings on pipe sections in accordance with this specification section.

- a. The nominal coating thickness for the metallic pipe joint or other component coating must be 16 mils, plus or minus 5 percent.
- b. Apply pipe and joint coating for factory applied or field repair material as recommended by the manufacturer. Coating must be one of the following:
 - (1) Continuously extruded polyethylene and adhesive coating system.
 - (2) Polyvinyl chloride pressure-sensitive adhesive tape.
 - (3) High density polyethylene/bituminous rubber compound tape.
 - (4) Butyl rubber tape.
 - (5) Coal tar epoxy.

2.1.2.14.4 Field Joints

Coat all field joints with materials compatible with the pipeline coating compound. Apply the joint coating material to an equal thickness as the pipeline coating. Do not use unbonded coatings for these buried metallic components. This includes the elimination of all unbonded polymer wraps or tubes. Once the pipeline or vessel is set in the trench, conduct an inspection of the coating. This inspection must include electrical holiday detection. Repair any damaged areas of the coating. The Contracting Officer or the Contracting Officer's Representative, Technical Expert or Project Manager must be asked to witness inspection of the coating and testing using a holiday detector.

2.1.2.14.5 Inspection of Pipe Coatings

Any damage to the protective coating during transit and handling must be repaired before installation. After field coating has been applied, inspect the entire pipe using an electric holiday detector in accordance with NACE SP0188 using a full-ring, spring-type coil electrode. The

holiday detector must be equipped with a bell, buzzer, or other type of audible signal which sounds when a holiday is detected. Upon detection, immediately repair all holidays in the protective coating. Occasional checks of holiday detector, operation will be made by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager to determine suitability of the detector. Provide all labor, materials, and equipment necessary for conducting the inspection.

2.1.2.14.6 Protective Coating for Aboveground Piping System

Provide finish painting conforming to the applicable paragraph of Section 09 90 00 PAINTS AND COATINGS and as follows:

2.1.2.14.7 Ferrous Surfaces

Touch-up shop-primed surfaces with ferrous metal primer. Solvent-clean surfaces that have not been shop-primed. Surfaces that contain loose rust, loose mill scale, and other foreign substances must be mechanically-cleaned by power wire-brushing and primed with ferrous metal primer. Finish primed surface with two coats of exterior oil paint and vinyl paint.

2.1.3 Performance Requirements

The design must allow for synchronized interruption of all applied current.

2.1.3.1 Criteria of Cathodic Protection

The design must allow for synchronized interruption of all applied current. All galvanic anode leads, or header cables, must be connected to the protected structure through test stations or junction boxes and must never be connected directly to the protected structure.

- a. Determination of the on and polarized (instant off) potentials must be made with the protective current applied to the pipeline for a minimum of 2 . Polarized potentials may be determined using a coupon test station (Error-Free (IR Free) test station). Polarized potentials must be determined by interrupting all the current being applied to the structure or coupon.
- b. The potential measurements for the native measurement and the polarized potential must be made with the reference electrode at the same exact location. The polarization decay measurements must also be made with the reference electrode at the same exact location as the polarization potential.
- c. The polarization decay measurements will be the difference between the polarized potential and a voltage measurement made 24 hours after the interruption of protective current.

2.1.3.1.1 Steel

A negative polarized potential of 0.85 volts (850 millivolts) or more negative. The voltage must not be more negative than a negative polarized potential of 1.200 volts (1200 millivolts).

2.1.3.1.2 Aluminum

Aluminum underground component must not be protected to a potential more

negative than minus 1200 millivolts, measured between the underground component and a saturated copper/copper sulfate reference electrode contacting the earth, directly over the metallic component. Resistance, if required, must be inserted in the anode circuit within the test station to reduce the potential of the aluminum to a value which will not exceed a potential more negative than minus 1200 millivolts. Voltage shift criterion must be a minimum negative polarization shift of 100 millivolts measured between the metallic component and a saturated copper/copper sulfate reference electrode contacting the earth, directly over the metallic component. The polarization voltage shift must be determined as outlined for iron and steel.

2.1.3.1.3 Copper Piping

For copper piping, the following criteria must apply: A minimum of 100 millivolts of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The polarization voltage shift must be determined as outlined for iron and steel.

2.2 EQUIPMENT

2.2.1 Remote Monitoring

Remote monitoring equipment must be designed, manufactured and procured specifically for cathodic protection use and must be provided as per design and drawings to monitor bond(s) and must match or be compatible with previously installed remote monitoring equipment in use at the installation.

2.2.2 Corrosion Rate Monitoring

Corrosion probes must be designed, manufactured and procured specifically for the application and matched to the structure being protected. Manufacturer must match or be compatible with previously installed rate monitoring equipment in use at the installation.

2.2.3 Polarization Cell Replacement (PCR) and (PCRH) for Hazardous Locations

PCRs and PCRHs must be designed, manufactured, and procured specifically for the application and must exceed the modeled AC steady-state current and fault conditions. For Hazardous locations, the PCRH model must be used.

Characteristic	PCR	PCRH
AC steady-state current, rms	45A, 80A	45A
AC fault current, rms. at 0.5s	3.7 kA to 15 kA	3.7 kA to 15 kA
Lightning current, 8x20 micros, peak	100 kA	100 kA

Characteristic	PCR	PCRH
Hazardous location certification	Division 2, Zone 2	Division 1, Zone 1
Rain Proof, IP66	Yes	Yes
Submersible, IP68 or NEMA 6P	Optional	No

PCRs must be installed with a protective ground-based enclosure to secure the cable connections and prevent electrical hazards. The PCRH must be installed with an explosion-proof enclosure and must be wall mounted. Structure and Grounding conductors must be properly sized for the application.

AC Fault Current Rating	Minimum Wire Size (AWG)	Minimum Wire Size (Metric)
1.2 kA, 2kA, 3.7 kA	#6	16mm ²
5kA 9kA 10kA	#2	35mm ²
14kA 15kA	#2/0	70mm ²

2.2.4 Solid State Decoupler (SSD)

SSDs must be designed, manufactured, and procured specifically for the application and must exceed the modeled AC steady-state current and fault conditions. For Hazardous locations, the PCRH model must be used. SSDs must be installed with a protective ground-based enclosure to secure the cable connections and prevent electrical hazards.

Characteristic	SSD
AC steady-state current, rms	45A
AC fault current, rms. at 0.5s	1.2 to 5 kA
Lightning current, 8x20micros, peak	75-100 kA
Hazardous location certification	Division 2, Zone 2

Characteristic	SSD
Rain Proof, IP66	Yes
Submersible, IP68 or NEMA 6P	Yes

2.3 COMPONENTS

2.3.1 Test Stations

2.3.1.1 Flush Mounted

NEMA ICS 6. Metallic or non-metallic with terminal board, 5 terminal posts and lockable lid. A non-metallic enclosure must be molded of glass filled polycarbonate and urethane coated or Acrylonitrile Butadiene Styrene (ABS) plastic and mounted on a 18 inch length of PVC conduit. The unit must be of standard design, manufactured for use as a CP test station, complete with cover, terminal board, shunts, and brass or Type 304 stainless steel hardware. The terminal board must be removable for easy access to wires. Provide traffic valve box capable of withstanding H-20 traffic loads. The cover must have a cast in legend "CP TEST."

2.3.1.2 Post Top Mounted

NEMA ICS 6. Metallic or non-metallic with terminal board, 5 terminal posts and lockable lid. A non-metallic enclosure must be high impact strength molded plastic. The unit must be of standard design, manufactured for use as a CP test station, complete with cover, terminal board, shunts, and brass or Type 304 stainless steel hardware. The terminal board must be removable for easy access to wires. The test station must be mounted atop 6 foot long polyethylene conduit with anchor. Terminal connections will be permanently tagged to identify each termination of conductors (e.g. identify the conductors connected to the protected structure, anodes, and reference electrodes).

2.3.1.3 Wall Mounted

NEMA ICS 6, Type 3R enclosure with clamped cover . Enclosure will be of galvanized steel construction with terminal board and labeled with nameplate. Provide nameplate in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Enclosure mounting posts must be galvanized steel pipe, schedule 40 , wood post, full length pressure treated with pentachlorophenol . Mount enclosure 42 inches above finished grade . Terminal connections will be permanently tagged to identify each termination of conductors (e.g. identify the conductors connected to the protected structure, anodes, and reference electrodes).

2.3.1.4 IR-Free Test Station

Must be wall mounted test station to include coupon of the same material as the structure, shunt, permanent reference electrode with means of momentary isolation of the coupon with provided circuitry designed, manufactured and procured exclusively for CP instant off testing of a

cathodically protected structure. Must be waterproof if used in flush test stations.

2.3.2 Shunts for Test Stations and Junction Boxes

MIL-I-1361. ohm, 2 ampere, accuracy plus or minus one percent, polycarbonate circuit board type, color coded for value recognition red for 0.1 ohm shunt with nickel-plated brass posts and standard 0.25 inch inch holes on 2.54 cm 1 inch centers to fit test stations and terminal boards 0.01 ohm 6 ampere, accuracy plus or minus one percent, manganin wire type.

2.3.3 Junction Box Enclosures

NEMA ICS 6, Type 3R enclosure with clamped cover . Enclosure must be of galvanized steel construction with terminal board. Knockout for conduit must be the size and location as per design drawings.

2.3.3.1 Nameplates

Provide nameplate in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and ASTM D709. Provide laminated plastic nameplates for each enclosure as specified or as indicated on the drawings. Each nameplate inscription must identify the function. Nameplates will be melamine plastic, 0.125 inch thick, white with black center core. Surface will be matte finish. Corners will be square. Accurately align lettering and engrave into the core. Minimum size of nameplates must be 25 inch by 2.5 inches. Lettering must be a minimum of 0.25 inch high normal block style.

2.3.4 Terminal Boards

Provide terminal boards for anode junction boxes, bonding boxes, and test stations made of phenolic plastic 1/8 inch thick with dimensions as indicated. Insulated terminal boards must have the required number of terminals (one terminal required for each conductor). Install solderless copper lugs and copper buss bars, shunts, and variable resistors on the terminal board as indicated. Test station terminal connections will be permanently tagged to identify each termination of conductors (e.g. identify the conductors connected to the protected structure, anodes, reference electrodes and coupons).

2.3.5 Anode Junction Boxes

2.3.5.1 Enclosure

NEMA ICS 6, Type 3R enclosure with clamped cover . Enclosure must be of galvanized steel construction with terminal board and labeled with nameplate. Provide nameplate in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.3.5.2 Terminal Boards

Provide terminal boards for anode junction boxes, bonding boxes, and test stations made of phenolic plastic 1/8 inch thick with dimensions as indicated. Insulated terminal boards must have the required number of terminals (one terminal required for each conductor). Install solderless copper lugs and copper buss bars, shunts, and variable resistors on the terminal board as indicated. Test station terminal connections will be permanently tagged to identify each termination of conductors (e.g.

identify the conductors connected to the protected structure, anodes, and reference electrodes).

2.4 MATERIALS

2.4.1 Galvanic Anodes

2.4.1.1 Dimensions and Weights

Bare anode weight 9 pounds not including core.

2.4.1.2 Standard Magnesium Anodes

Install a minimum of 2 anodes on the Pipe system. See Paragraph METALLIC COMPONENTS ON NON-METALLIC SYSTEMS AND TYPICALS for additional anodes under slab.

2.4.1.2.1 Anode Composition

Anodes must be of high-potential magnesium alloy, made of primary magnesium obtained from sea water or brine, and not made from scrap metal. Magnesium anodes must conform to ASTM B843 and to the following analysis (in percent) otherwise indicated:

Aluminum	0.010 percent
Manganese	0.50 to 1.30 percent max
Zinc	0.05 percent max
Silicon	0.05 percent max
Copper	0.02 percent max
Nickel	0.001 percent max
Iron	0.03 percent max
Other impurities	0.05 each or 0.3 percent max total
Magnesium	Remainder

Furnish spectrographic analysis on samples from each heat or batch of anodes used on this project.

2.4.1.2.2 Dimensions and Weights

The following dimensions and weights of anodes are not all inclusive and are presented as examples, various manufacturers may have additional sizes not included in the following table:

- a. Bare anode weight: 9 pounds .

Typical Magnesium Anode Size (may be round, square, or D shaped)													
Nominal Weight Bare		Approximate Size						Packaged Weight		Nominal Packaged Dimensions			
kg	lbs	Width		Height		Length		kg	lbs	Diameter		Length	
		mm	inch	mm	inch	mm	inch			mm	inch	mm	inch
	1		1.75		1.75		8		5		3.25		9
	3		3.5		3.75		5		8		6		10
	5		3.5		3.75		8.5		17		6		12
	9		2.75		3		27	15.9	35		5.5		32
	9		3.5		3.75		14		27		6		17
	17		2.75		2.75		50.25		60		6		55
	17		3.5		4		25.75		45		6.5		29
	20		2.75		3.75		59.75		70		5		66
	32		3.5		3.75		45.25		91		6.5		53
	32		5.5		5		20.5		70		8		28
	40		3.5		3.75		59.75		96		6.5		66
	48		5.5		5.75		31		100		8		38
	60		4		4		60		125		7		64

2.4.1.2.3 Packaged Anodes

Provide anodes in packaged form with the anode surrounded by specially-prepared quick-wetting backfill and contained in a water permeable cloth or paper sack. Anodes must be centered by means of spacers in the backfill material.

The backfill material will have the following composition, unless otherwise indicated:

Material	Approximate Percent by Weight
Gypsum	75
Bentonite	20
Sodium Sulfate	5
Total	100

2.4.1.3 Cast Zinc Anodes

ASTM B418, Type I . Bare anode weight: 5 pounds not including core.

Bare Weight		Width		Height		Length		Total Packaged Weight	
kg	pounds	mm	inches	mm	inches	mm	inches	kg	pounds
	5		1.4		1.4		10		20
	12		1.4		1.4		24		40
	15		1.4		1.4		30		50
	15		2.0		2.0		15		36
	18		1.4		1.4		36		55
	30		1.4		1.4		60		86
	30		2.0		2.0		30		67
	45		2.0		2.0		45		100
	60		2.0		2.0		60		120

2.4.1.3.1 Anode Composition

Chemical composition as follows:

Zinc	4.5 percent maximum
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2.4.1.4 Aluminum Anodes

2.4.1.4.1 Anode Composition

Chemical composition as follows:

Zinc	4.5 percent maximum
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2.4.1.4.2 Dimensions and Weights

Anode Weight pounds not including core.

2.4.1.4.3 Anode Core

Iron galvanized steel rod pipe , 1/8 inch diameter by .

2.4.2 Wire and Cable

2.4.2.1 Anode Lead Wire

Wire must be No. 12 AWG solid copper wire, not less than 10 feet long, without any splices, complying with NFPA 70, Type Thermoplastic Heat and Water-resistant Nylon-coated (THHN) THHN Rubber Heat (resistant) Wire (RHW) RHW-USE insulation. Connecting wires for magnesium anodes will be factory installed with the place or emergence from the anode in a cavity-sealed flush with a dielectric sealing compound.

2.4.2.2 Bolted Connected Anodes

UL 83, Type THWN , solid copper conductors, not less than No. 12 AWG, 10 feet long, of sufficient length to extend to the accompanying junction box without splicing. Anode lead wire will be factory installed. Silver solder the lead wire to the anode core, and seal the soldered connection and recessed end of the anode with an asphaltic dielectric sealing compound. Dielectric material must extend past the connection and cover the lead wire insulation by not less than 1/2 inch. Cover the connection with heat-shrinkable tubing.

2.4.2.3 Anode Header Cable

Cable for anode header and distribution will be No. AWG stranded copper wire with type CP HMWP, 7/64 inch thick insulation, 600-volt rating.

2.4.2.4 Structure (Negative) Cable

Structure connecting wire must be No. 4 AWG stranded copper wire with type THHN insulation, 600 volt rating. Copper conductors conforming to ASTM B3 and ASTM B8.

2.4.2.5 Test Wires

Test wires must be No. 12 AWG stranded copper wire with NFPA 70 Type Thermoplastic Wire (TW) or RHW or polyethylene insulation. Copper conductors conforming to ASTM B3 and ASTM B8.

2.4.2.6 Joint and Continuity Bond Cables

Provide bonds across joints or any electrically discontinuous connections in the piping, and other pipes and structures with other than welded or threaded joints included in this CP system. Unless otherwise specified, bonds between structures and across joints in pipe with other than welded or threaded joints must be with No. 4 AWG stranded copper cable with polyethylene insulation. Bonds between structures must contain sufficient slack for any anticipated movement between structures. Bonds across pipe joints must contain a minimum of 4 inch of slack to allow for pipe movement and soil stress. Bonds must be attached by exothermic welding. Exothermic weld areas must be insulated with coating compound and approved by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Continuity bonds must be installed as necessary to reduce stray current interference. Additional joint bonding must be done where determined during construction or testing or as directed. Joint bonding must include excavation and backfilling. There must be a minimum of 2 continuity bonds between each structure and other than welded or threaded joints. Electrical continuity must be tested across joints with other than welded or threaded joints and across metallic portions of sewage lift stations and water booster stations. Copper conductors conforming to ASTM B3 and ASTM B8.

2.4.2.7 Resistance Bond Wires

Resistance bonds must be adjusted for minimum interference while achieving the criteria of protection. Alternate methods may be used when approved.

2.4.2.8 Polyethylene Insulation

Polyethylene insulation must comply with the requirements of ASTM D1248 and of the following types, classes, and grades:

2.4.3 Cable and wire Identification Tags

Brass material with engraved letters. Print letters and numbers a minimum of 3/16 inch in height. Provide identifier legend in accordance with the drawings .

2.4.4 Anode Connection

2.4.4.1 End-Connected Anode

Drill a recess 6 inches deep in one end of the anode. Attach the lead wire to the anode with an anchor device. Not more than 1/2 inch of bare wire must protrude from the anchor device. Attachment must withstand a 325 pound pull without loosening the wire or anchor device. Fill the recess with an epoxy sealing compound , leaving sufficient space for a plug. Provide non-metallic plug flush with the anode end surface. Cable-to-anode contact resistance must not exceed 0.02 ohms.

2.4.4.2 Center-Connected Anode

Attach the lead wire to the center of the anode with an anchor device suitably fastened to the wire. Not more than one inch of bare wire must protrude from the anchor device. Encapsulate each side of the connection point with a minimum of 6 inches of high voltage insulating compound mastic and 4 inches of epoxy resin. Attachment must withstand 900 pounds

pull without loosening the wire or anchor device. Provide a non-metallic plug flush with the anode end to prevent chaffing of the anode lead wire. Cable-to-anode contact resistance must not exceed 0.02 ohms.

2.4.5 AC Mitigation Materials

If required, AC mitigation materials typically consist of a mitigation material either zinc ribbon or copper cable, interconnecting coated copper cables, solid state decouplers to control the AC current flow and test stations.

2.4.6 Backfill Material

The backfill material must have the following composition, unless otherwise indicated:

Material	Approximate Percent by Weight
Gypsum	75
Bentonite	20
Sodium Sulfate	5
Total	100

2.4.7 Permanent Reference Electrodes

Permanent reference electrodes must be copper/copper-sulfate specifically manufactured for underground use, 1 1/4 inch diameter, by 8 inches long, plastic tube with an ion trap to minimize contamination of the electrode. Must never need recharging, maintenance, or recalibration. Must have impregnated membrane which keeps electrode electrolytes from drying out or getting the reference electrode electrolyte contaminated. Must have ion trap to prevent reference electrode damage from hydrogen sulfide or excess chloride ions. The electrode will be prepackaged by the manufacturer with a backfill material as recommended by the manufacturer. Provide electrodes with No. 10 AWG, THHN cable of sufficient length to extend to the test station without splicing. Reference electrodes will have a minimum 20-year life, stability of plus or minus 5 millivolts under 3 microamp load. The manufacturer must calibrate the PRE to 316 mV plus or minus 10mV referenced to a standard hydrogen electrode (SHE) and provide a calibration certificate detailing the results of the calibration. Procedures for evaluating the accuracy annually must be included in the Operation and Maintenance Manual.

2.4.8 Pavement Inserts

Pavement insert must be a non-metallic flush type test station without terminal board, and must allow a copper/copper sulfate reference electrode to contact the electrolyte beneath the pavement surface. Provide traffic valve box capable of withstanding H-20 traffic loads.

2.4.9 Coupons

Coupons must match the material of the structure, with 1 integrated connection(s) with electrical wire(s) and be designed, manufactured and procured for use as a corrosion coupon, IR-Free reference electrode, or AC

reading electrode.

2.4.10 Zinc Grounding Cells

Two Zinc Type II anodes separated with 1 inch isolating spacers. Minimum 10 feet of #6 AWG HMWPE CP cable crimped securely to each anode. Both anodes centered in one cloth bag and surrounded with low resistance backfill mixture consists of 75 percent hydrated gypsum, 20 percent bentonite, and 5 percent sodium sulfate.

Element	Content Percent	
	MIL-A-18001 ASTM B418 Type I	ASTM B418 Type II
Al	0.1 - 0.5 percent	0.005 percent max
Cd	0.02 - 0.07 percent	0.003 percent max
Fe	0.005 percent max	0.0014 percent max
Pb	0.006 percent max	0.003 percent max
Cu	0.005 percent max	0.002 percent max
Zinc	Remainder	Remainder

Bare Weight		Width		Height		Length		Total Packaged Weight	
kg	pounds	mm	inches	mm	inches	mm	inches	kg	pounds
	5		1.4		1.4		10		20
	12		1.4		1.4		24		40
	15		1.4		1.4		30		50
	15		2.0		2.0		15		36
	18		1.4		1.4		36		55
	30		1.4		1.4		60		86
	30		2.0		2.0		30		67
	45		2.0		2.0		45		100
	60		2.0		2.0		60		120

2.4.11 Isolation Flange Kits

Provide full-faced gaskets, isolating sleeves and washers, and steel washers. Provide isolation flange kits rated for operation at the rated pressure and temperature.

2.4.11.1 Gaskets

ASME B16.21. Neoprene faced phenolic material for operation at psi, 450 degrees F.

2.4.11.2 Isolating Washers and Sleeves

Two sets 1/8 inch laminated phenolic for operation at 450 degrees F. Isolating washers must fit within the bolt facing on the flange over the outside of the fabric reinforced phenolic sleeve.

2.4.11.3 Washers

Steel, cadmium plated, to fit within the bolt facing on the flange.

2.4.12 Steel Flanges and Bolting

2.4.12.1 Steel Flanges

ASME B16.5, 150 lb. .

2.4.12.2 Bolting

ASTM A307, Grade B for bolts; ASTM A194/A194M, Grade 2 for nuts. Dimensions: ASME B18.2.1 for bolts, ASME B18.2.2 for nuts. Threads: ASME B1.1, Class 2A fit for bolts, Class 2B fit for nuts. Bolts must extend completely through the nuts and may have reduced shanks of a diameter not less than the diameter at the roof of threads.

2.4.13 Dielectric Unions

ASME B16.39, Class 1 for dimensional, strength, and pressure requirements. Insulation barrier must limit galvanic current to one percent of the short-circuit current in a corresponding metallic joint. Provide insulating material impervious to water .

2.4.14 Isolation and End Seals

2.4.14.1 Casing Isolator/Centralizer

High density (linear), injection molded virgin Polyethylene positive electrical isolation, high abrasion resistance and low coefficient of friction.

2.4.14.2 End Seals

Ethylene Propylene Diene Monomer (EPDM) Neoprene rubber end seals, thickness of 1/8 inch or more, with 2 Stainless Steel Pipe Clamps per end seal, 1/8 inch thick and 1/2 inch wide or more.

2.5 ACCESSORIES

2.5.1 Conduit

UL 6, rigid galvanized steel, Outlet boxes: UL 514A and fittings UL 514B, threaded hubs. Metallic conduit and fittings to be PVC coated in accordance with NEMA RN 1, Type A40, NEMA TC 2, Type EPC-40-PVC. Non-metallic conduit must conform to NEMA TC 2.

2.5.2 Joint, Patch, Seal, and Repair Coating

Sealing and dielectric compound must be a black, rubber based compound that is soft, permanently pliable, tacky, moldable, and unbacked. Compound will be applied as recommended by the manufacturer, but not less than 1/2-inch thick. Coating compound must be cold-applied coal-tar base mastic . Pressure-sensitive vinyl plastic electrical tape and rubber insulated tape must conform to UL 510.

2.5.3 Underground Splices

Provide splices with a compression connector on the conductors, and insulation and waterproofing using one of the following methods which are suitable for continuous submersion in water and comply with ANSI C119.1.

2.5.3.1 Cast-Type Splice

Provide cast-type splice insulation by means of molded casting process employing a thermosetting epoxy resin insulating material applied by a gravity poured method or pressure injected method. Provide component materials of the resin insulation in a packaged form ready for convenient mixing without removing from the package.

2.5.3.2 Gravity-Poured Splice

Gravity-poured method must employ materials and equipment contained in and approved commercial splicing kit which includes a mold suitable for the cables to be spliced. When the mold is in place around the joined conductors, prepare the resin mix and pour into the mold.

2.5.3.3 Heat Shrinkable Splice

Provide heavy wall heat shrinkable splice insulation by means of a thermoplastic adhesive sealant material which must be applied by a clean burning propane gas torch.

2.5.4 Electrical Isolation of Structures

2.5.4.1 Electrically Isolating Pipe Joints

Electrically isolating pipe joints will be of a type that is in regular factory production.

2.5.4.2 Electrically Isolating Couplings

Electrically isolating couplings will be of a type that has a published maximum electrical resistance rating given in the manufacturer's literature. Cradles and seals will be of a type that is in regular factory production made for the purpose of electrically isolating the carrier pipe from the casing and preventing the incursion of water into the annular space.

2.5.5 Electrical Insulating Coating

Heat-shrinkable tape .

2.5.6 Buried Cable Warning and Identification Tape

Polyethylene tape, manufactured for warning and identification of buried cable and conduit. Tape must be 3 inches wide, Yellow in color and read "Caution Buried Cable Below" or similar. Color and lettering must be permanent and unaffected by moisture or other substances in backfill materials.

2.5.7 Electrical Connection to Structures

2.5.7.1 Exothermic Welds

Electrical connections to metallic structures must be made using exothermic welds in strict accordance with the manufacturer's recommendations.

2.5.7.2 Electrical-Shielded Arc Welds

Electrical-shielded arc welds must be approved for use on steel pipe by shop drawing submittal action.

2.5.7.3 Brazing

Brazing will be as specified by manufacturer using specialized equipment designed for that purpose.

2.5.8 Electrical Tape

Pressure-sensitive vinyl plastic electrical tape and rubber insulated tape must conform to UL 510.

2.5.9 Exothermic Weld Kits

Exothermic weld kits specifically designed by the manufacturer for exothermic welding wires to metallic surfaces. Molds must be for specific type of metallic structure (steel, cast iron), specific diameter of pipe or metallic surface and specific size (AWG)and type of wire (solid, stranded).

2.6 TESTS, INSPECTIONS, AND VERIFICATIONS

2.6.1 Non-Destructive Testing of Anodes

Contractor must perform the tests in the presence of the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. One anode of each type will be chosen at random for non-destructive testing and will be submerged in a container of fresh water for about 30 minutes. Contractor must then measure the anode-to-water potential difference between a calibrated copper/copper sulfate reference electrode. Potential differences must generally be within the following ranges:

Anode Type	DC Volts to Calibrated Cu/CuSO4 Reference Electrode
High Potential Magnesium	More Negative than Negative 1.65 Volts DC
Standard Magnesium	More Negative than Negative 1.4 Volts DC

Anode Type	DC Volts to Calibrated Cu/CuSO ₄ Reference Electrode
Zinc	More Negative than Negative 1.0 Volts DC
Aluminum	More Negative than Negative 1.0 Volts DC

Failure of the test anode to conform to this specification can be cause for rejecting all anodes from the same lot as the test anode. The contractor must mark all rejected anodes on the ends with a 6 inch high "X" using yellow spray paint. Failed anodes must be removed from the job site by the end of the day. The contractor must replace any rejected anodes at the contractor's expense. The destructive testing provision must also apply to replacement anodes as well.

2.6.2 Destructive Testing of Anodes

Contractor must perform the tests in the presence of the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Contractor must include the cost of an additional anode of each different type with the longest lead wire for the destructive test in the contractor's bid. One completed prepackaged anode of each type with lead wires will be chosen at random for destructive testing and must be submitted to a static pull test. Anode wire connections must have sufficient strength to withstand a minimum tensile load of 300 pounds. The anode must be cut into sections or broken with a sledgehammer to verify conformance with this specification. Such items as anode-to-wire connection, complete encapsulation of the wire connector, and wire to anode electrical resistance must be checked.

PART 3 EXECUTION

3.1 SAFETY PRECAUTIONS AND HAZARDOUS LOCATIONS

Any personnel performing operations that will generate heat, sparks, or flame in hazardous locations must first perform adequate safety precautions. A trained responsible person must ensure the area is safe to perform the operation. Required actions include ensuring adequate ventilation before work starts, air monitoring, and a fire watch must be provided and remain for 30 minutes after the operation is completed. A minimum of 20 pound ABC type fire extinguisher must be available and must be inspected before each use. Equipment being used must be inspected and used in accordance with manufacturer recommendations. Combustibles that are in the work area(s) must be moved or if they cannot be moved, be covered with fire retardant welding blankets. When performing exothermic welding, properly sized charges and inspection of the structure condition must be accomplished to ensure a safe operation.

3.2 INSTALLATION

3.2.1 Excavation and Trenching

Perform trenching and backfilling in accordance with Section 31 00 00 EARTHWORK . In the areas of the anode beds, all trees and underbrush will be cleared and grubbed to the limits shown or indicated. In the event rock is encountered in providing the required depth for anodes, determine an alternate approved location and, if the depth is still not provided, submit an alternate plan to the Contracting Officer or the Contracting

Officer's Representative, Technical Expert and Project Manager. Alternate techniques and depths must be approved prior to implementation.

3.2.2 Anode Excavation

- a. Excavate hole to a minimum 3 inches larger than the packaged anode diameter, feet deep.

3.2.3 Lead Wire Trench

- b. Excavate lead wire trench to 24 inches deep, inches wide.

3.3 ANODES AND LEAD WIRE

3.3.1 Anode Installation

Unless otherwise authorized, installation must not proceed without the presence of the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Anodes of the size specified must be installed to the depth indicated and at the locations shown. Locations may be changed to clear obstructions with the approval of the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Anodes will be installed in sufficient number and of the required type, size, and spacing to obtain a uniform current distribution over the surface of the structure. The anode system will be designed for a life of 25 years of continuous operation. Anodes must be installed as indicated in a dry condition after any plastic or waterproof protective covering has been completely removed from the water permeable, permanent container housing the anode metal. The anode connecting wire must not be used for lowering the anode into the hole. The annular space around the anode must be backfilled with fine earth in 6 inch layers and each layer must be hand tamped.

3.3.1.1 Single Anodes

Single anodes, spaced as shown, will be connected to the pipeline, allowing adequate slack in the connecting wire to compensate for movement during backfill operation.

3.3.1.2 Group of Anodes

Groups of anodes, in quantity and location shown, must be connected to an anode header cable. The anode header cable must make contact with the structure to be protected only through a test station. Anode lead connection to the anode header cable must be made by an approved crimp connector or exothermic weld and splice mold kit with appropriate potting compound.

3.4 INSTALLATION DETAILS

3.4.1 Anode Installation

Do not lift or support anode by the lead wire. Where applicable, remove manufacturer's plastic wrap/bag from the anode. Exercise care to preclude damaging the cloth bag and the lead wire insulation. Center the packaged anode in the hole with native soil in layers not exceeding 6 inches. Hand tamp each layer to remove voids taking care not to strike the anode lead wire. When the backfill is 6 inches above the top of the anode, pour at least ten gallons of water into the hole to saturate the anode backfill

and surrounding soil. Anodes must not be backfilled prior to inspection and approval by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager.

3.4.2 Lead Wire Installation

Cover the lead wire trench bottom with a 3 inch layer of sand or stone free earth. Center wire on the backfill layer. Do not stretch or kink the conductor. Place backfill over wire in layers not exceeding six inches deep. Compact each layer thoroughly. Do not place tree roots, wood scrap, vegetable matter and refuse in backfill. Place cable warning tape within 18 inches of finished grade, above cable and conduit.

3.4.2.1 Lead Wire Connections

Connect anode lead wire(s) to the test station terminal board(s). The coating must be completely cured before backfilling. Allow sufficient slack in the lead wire to compensate for movement during backfilling operation.

3.4.2.2 Field Drawing

Complete a field drawing of each anode installation showing location of anode, test station, depth of anode, color and size of anode lead wire and any other pertinent details. Submit copy with daily report to the government.

3.4.2.3 Metallic Underground Pipeline Connection

To facilitate periodic electrical measurements during the life of the sacrificial anode system and to reduce the output current of the anodes, if required, all anode lead wires must be connected to a test station and buried a minimum of 24 inches in depth. The cable must be No. 10 AWG, stranded copper, polyethylene or RHW-USE insulated cable. The cable must make contact with the structure only through a test station. Resistance wire must be installed between the cable and the pipe cable, in the test station, to reduce the current output, if required. Anode connections, except in the test station, must be accomplished by exothermic welding, and must be insulated by means of at least three (3) layers of electrical tape; and all lead wire connections must be installed in a moisture-proof splice mold kit and filled with epoxy resin. Lead wire-to-structure connections must be accomplished by an exothermic welding process. All welds must be in accordance with the manufacturer's recommendations. A backfill shield filled with a pipeline mastic sealant and material compatible with the coating must be placed over the weld connection and be of such diameter as to cover the exposed metal adequately. Anodes must be installed at a minimum of 8 feet and a maximum of 10 feet from the structure to be protected.

Contractor must take proper safety precautions prior to and during welding to live pipelines tanks. Contractor must notify the activity Fuel Office via the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager a minimum of three days before performing exothermic welding to live lines. Exothermic welding must be conducted with product flowing through the pipeline to eliminate vapor spaces within the pipe and to dissipate the heat on the pipe. Exothermic weld charges for connections to live lines must be limited to a maximum 15 gram charge to prevent burning through the pipe wall. Exothermic weld connections must be spaced a minimum of 6 inches apart. In the event of an

unsuccessful weld, the new weld location must be located a minimum of 6 inches from the unsuccessful weld and any other existing welds. Contractor must obtain the services of a certified safety professional to monitor the construction site during exothermic welding work and certify that the area is free of flammable vapors and otherwise safe for work.

3.4.3 Underground Pipe Joint Bonds

Underground pipe having other than welded or threaded coupling joints must be made electrically continuous by means of a bonding connection installed across the joint.

3.4.4 Anode Junction Boxes

Provide junction boxes and mark each of the wires terminating in each box.

3.4.5 Bonding Boxes

Provide structure bonding boxes in locations as indicated .

3.4.6 Test Stations and Permanent Reference Electrodes

Test stations will be of the type and location shown and will be curb box mounted. Provide buried isolation joints with test wire connections brought to a test station. Reference all test stations with GPS coordinates. Unless otherwise shown, locate other test stations and permanent reference electrodes as follows:

- a. At 1000 foot intervals.
- b. At all isolation joints.
- c. At both ends of casings.
- d. Where the pipe crosses any other metal pipes.
- e. Where the pipe connects to an existing piping system.
- f. Where the pipe connects to a dissimilar-metal pipe.

Do not fill the bottom of the test station with concrete unless otherwise specified. Do not place rubbish, scrap or other debris into the test station.

3.4.7 Permanent Reference Electrode Verification

Verify permanent reference electrodes against a calibrated portable electrode in the presence of the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager before installation. Verify in a non-metallic container of water. Permanent electrode must measure a reference potential agreeing with that measured by the portable electrode within plus or minus 0.010 volts when the sensing windows of the two electrodes being compared are not more than 1/6 inch apart but not touching. Remove permanent reference electrodes not within this potential range from the construction site by the end of the day and replace at the contractor's expense. The testing provision applies to replacement permanent reference electrodes as well.

3.4.7.1 Field Drawings

Complete a field drawing of each anode installation showing location of anode, depth of anode, color and size of anode lead wire and any other pertinent details . Submit copy with daily report to the government.

3.5 ELECTRICAL ISOLATION OF STRUCTURES

3.5.1 Isolation Fittings

Isolating fittings, including isolating flange kits, dielectric unions and couplings, must be installed aboveground, or within manholes, wherever possible. Where isolating joints must be covered with soil, they must be fitted with a proper joint cover specifically manufactured for covering the particular joint, and the space within the cover filled with hot coal-tar enamel or hot petrolatum wax. Isolating fittings in lines entering buildings must be located at least 12 inch above grade of floor level, when possible. Isolating joints must be provided with grounding cells to protect against over-voltage surges or approved surge protection devices. The cells must provide a low resistance across isolating joint without excessive loss of cathodic current.

3.5.2 Dielectric Unions

Cut pipe ends square, remove fins and burrs, cut taper pipe threads in accordance with ASME B1.20.1. Provide isolation unions as indicated. Work piping into place without springing or forcing. Apply joint compound or thread tape to male threads only. Backing off to permit alignment of threaded joints will not be permitted. Engage threads so that not more than three threads remain exposed. Cover unions with an electrically insulating coating.

3.5.3 Gas Distribution Piping

Electrical isolation will be provided at each building riser pipe to the pressure regulator, at all points where a short to another structure or to a foreign structure may occur, and at other locations as indicated on the drawings. If an isolating joint is located inside a vault, the pipe must be sleeved when entering and leaving the vault. A non-metallic sleeve is to be used.

3.5.4 Joint Bonds

Provide joint bonds on metallic pipe to and across buried flexible couplings, mechanical joints, flanged joints except at places where isolation joints are specified and joints not welded or threaded to provide electrical continuity. Connect bond wire(s) to the structure(s) by use of exothermic weld kit(s). Clean the structure surface by scraping, filing or wire brushing to produce a clean, bright surface. Weld connections using exothermic kits in accordance with the kit manufacturer's instructions. Check and verify adherence of the bond to the substrate for mechanical integrity by striking the weld with a 2 pound hammer. Cover connections with an electrically insulating coating which is compatible with the existing coating on the structure.

3.5.5 Casings, Isolation, and Seals

Where the pipeline is installed in a casing under a roadway or railway, isolate the pipeline from the casing, and seal the annular space against

intrusion of water.

3.6 FIELD QUALITY CONTROL

Field tests must be witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager or their designated representative. Advise the Contracting Officer or Contracting Officer's Representative 5 days prior to performing each field test. Quality control for the cathodic protection system must consist of the following:

- a. Initial field testing by the contractor upon construction.
- b. Government Field Testing after contractor initial field test report submission.
- c. Warranty period field testing by the contractor.
- d. Final field testing by the contractor after one year of service.

3.6.1 Tests and Measurements

3.6.1.1 Native Potentials

Notify the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager a minimum of five (5) working days prior to each test. Base potential tests: At least one week after backfilling of the pipe and installation of the anodes, but before connection of anodes to the structure, measure base (native) structure-to-electrolyte potentials of the structure. Perform measurements at anode junction boxes, test stations and other locations suitable for test purposes (such as service risers or valves), at intervals not exceeding 100 feet with readings at each end point and the midpoints as a minimum. The locations of these measurements must be identical to the locations specified for potential measurements with anodes connected. Use the same measuring equipment that is specified for measuring protected potential measurements.

3.6.1.2 Protected Potentials

Systems must be tested and inspected by the contractor's corrosion engineer in the presence of the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager corrosion protection engineer or an approved representative. Notify the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager a minimum of five working days prior to each test. At least 24 hours after native potential testing and connection of anodes to the structure, measure protected structure-to-electrolyte potentials. The locations of these measurements must be identical to the locations specified for native potential measurements. For underground storage tanks, take a minimum of three measurements with the reference electrode located as follows: Directly over the longitudinal and transverse centerlines of the tank at intervals not exceeding the diameter of the tank and to a distance from the tank of two times the tank diameter. Use the same measuring equipment that is specified for measuring protected potential measurements. Record test data, including date, time, and locations of testing and submit report to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Contractor must correct and retest, at the contractor's and

Technical Expert's expense, deficiencies in the materials and installation observed by these tests and inspections.

3.6.1.3 Isolation Testing

Before the anode system is connected to the pipe , an isolation test must be made at each isolating joint or fitting. This test will demonstrate that no metallic contact, or short circuit exists between the two isolated sections of the pipe . Any isolating fittings installed and found to be defective must be reported to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager.

3.6.1.4 Isolation Tester

An Isolation Tester designed and manufactured for use in CP, using the continuity check circuit, must be used for all isolating joint (flange) electrical testing. Testing must conform to the manufacturer's operating instructions. Test must be witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. An isolating joint that is good will read full scale on the meter. If an isolating joint is shorted, the meter pointer will be deflected or near zero on the meter scale. Location of the fault will be determined from the instructions, and the joint must be repaired.

3.6.1.5 Anode Output

As the anodes or groups of anodes are connected to the pipe , current output will be measured with an approved clamp-on milliammeter, calibrated shunt with a suitable millivoltmeter or multimeter, or a low resistance ammeter. (Of the three methods, the low-resistance ammeter is the least desirable and most inaccurate. The clamp-on milliammeter is the most accurate.) The values obtained and the date, time, and location must be recorded.

3.6.1.6 Reference Electrode Potential Measurements

Upon completion of the installation and with the entire CP system in operation, electrode potential measurements must be made using a copper/copper sulfate reference electrode and a potentiometer-voltmeter, or a direct-current voltmeter having an internal resistance (sensitivity) of not less than 10 megohms per volt and a full scale of 10 volts. The locations of these measurements must be identical to the locations used for baseline potentials. The values obtained and the date, time, and locations of measurements must be recorded. No less than eight (8) measurements will be made over any length of line or component. Additional measurements will be made at each distribution service riser, with the reference electrode placed directly over the service line.

3.6.1.7 Casing Tests

Before final acceptance of the installation, the electrical isolation of carrier pipe from casings must be tested and any short circuits corrected.

3.6.1.8 Holiday Test

Any damage to the protective coating during transit and handling must be repaired before installation. After field-coating has been applied, the entire pipe must be inspected by an electric holiday detector with impressed current in accordance with NACE SP0188 using a full-ring,

spring-type coil electrode. The holiday detector will be equipped with a bell, buzzer, or other type of audible signal which sounds when a holiday is detected. Holidays in the protective coating must be repaired upon detection. Occasional checks of holiday detector potential will be made by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager to determine suitability of the detector. Labor, materials, and equipment necessary for conducting the inspection must be furnished by the contractor. The coating system must be inspected for holes, voids, cracks, and other damage during installation.

3.6.1.9 Stray Current Measurements

Before final acceptance of the installation, stray current tests must be performed on any foreign pipes in close proximity to the installed anodes. A full report of the tests giving all details must be made.

3.6.1.10 Induced AC Testing

Before final acceptance of the installation, induced AC Voltage tests must be performed on the pipes near high AC Voltage infrastructure and where crossing above ground and underground AC transmission systems. A full report of these tests must be included in the final testing reports with all details and data taken. The touch potential of any testing over 5 volts must be reported to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Any touch potential over 10 Volts must be mitigated by effective mitigation techniques. Refer to NACE SP0177 and NACE SP21424.

3.6.1.11 Interference Tests

Before final acceptance of the installation, interference tests will be made with respect to any foreign pipes in cooperation with the owner of the foreign pipes. A full report of the tests giving all details must be made. Stray current measurements must be performed at all isolating locations and at locations where the new pipeline crosses foreign metallic pipes; results of stray current measurements must also be submitted for approval. The method of measurements and locations of measurements must be submitted for approval. As a minimum, stray current measurements must be performed at the following locations:

- a. Connection points of new pipeline to existing pipeline.
- b. Crossing points of new pipeline with other existing metallic pipelines.

3.6.1.12 Initial Cathodic Protection System Field Testing

Initial field testing must be completed by the contractor upon completion of construction. Field testing must be witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager or their designated representative. Advise the Contracting Officer or Contracting Officer's Representative 5 days prior to performing each field test. Field testing must include native and protected potentials, and anode current testing.

The contractor must submit an initial field test report of the cathodic protection system. All structure-to-electrolyte measurements, including initial potentials, anode outputs, and other required testing must be

recorded on applicable forms. Identification of test locations, test station and anode test stations will coordinate with the as-built drawings and be provided on system drawings included in the report. The contractor must locate, correct, and report to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager any short circuits encountered during the checkout of the installed CP system.

3.6.1.13 Government Field Testing

The government corrosion program manager must review the contractor's initial field testing report. Approximately four weeks after receipt of the contractor's initial test report, the system will be tested and inspected in the contractor's presence by the government corrosion program manager. The contractor must correct, at the contractor's expense, materials and installations observed by these tests and inspections to not be in conformance with the plans and specifications. The contractor will pay for all retesting done by the government engineer made necessary by the correction of deficiencies.

3.6.1.14 One-Year-Warranty-Period-Testing

The contractor must inspect, test, and adjust the cathodic protection system semi-annually for one year, 4 interim inspections total, to ensure its continued conformance with the criteria outlined below. The performance period for these tests will commence upon the completion of all cathodic protection work, including changes required to correct deficiencies identified during initial testing, and preliminary acceptance of the cathodic protection system by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Copies of the One Year Warranty Period Cathodic Protection System Field Test Report, including field data, and certified by the contractor's corrosion engineer must be submitted to the Contracting Officer or Contracting Officer's Representative, the activity, and the geographic EFD corrosion Contracting Officer .

3.6.1.15 Final Acceptance Field Testing

Conduct final field testing of the cathodic protection system utilizing the same procedures specified under, "Initial Field Testing of the Galvanic Cathodic Protection Systems". The contractor will inspect, test, and adjust the cathodic protection system after one year of operation to ensure its continued conformance with the criteria outlined below. The performance period for these tests will commence upon preliminary acceptance for the cathodic protection system by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Copies of the Final Cathodic Protection System Field Test Report, certified by the contractor's corrosion engineer must be submitted to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager and the geographic EFD corrosion program manager for approval, and as an attachment to the operation and maintenance manual in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. The government corrosion program manager must review the contractor's final field testing report.

3.7 CLOSEOUT ACTIVITIES

3.7.1 Reconditioning of Surfaces

3.7.1.1 Concrete

Concrete must be 3000 psi minimum ultimate 28-day compressive strength with one inch minimum aggregate conforming to ASTM C94/C94M .

3.7.1.2 Restoration of Sod

Restore unpaved surfaces disturbed during the installation of anodes and wires to their original elevation and condition. In areas where grass cover exists, it is possible that sod can be carefully removed, watered, and stored during construction operations, and replaced after the operations are completed since it is estimated that no section of pipeline must remain uncovered for more than two (2) days. Where the surface is disturbed in a newly seeded area, re-seed the area with the same quality and formula of seed as that used in the original seeding. Seeding must be done as directed, in all un surfaced locations where sod and topsoil could not be preserved and replaced. The use of sod in lieu of seeding will require approval by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager.

3.7.1.3 Restoration of Pavement

Repair pavement, sidewalks, curbs, and gutters where existing surfaces are removed or disturbed for construction. Saw cut pavement edges. Graded aggregate base course must have a maximum aggregate size of 1 1/2 inches. Prime base course with liquid asphalt, ASTM D2028/D2028M, Grade RC-70 prior to paving. Match base course thickness to existing but must not be less than 6 inches. Asphalt aggregate size must be 1/2 inch , asphalt cement must conform to ASTM D3381/D3381M, Grade AR-2000 . Match asphalt concrete thickness to existing but must not be less than 2 inches. Repair Portland cement concrete pavement, sidewalks, curbs, and gutters using 3,000 psi concrete conforming to Section 03 30 00 CAST-IN-PLACE CONCRETE. Match existing pavement, sidewalk, curb, and gutter thicknesses.

3.7.1.4 Cleanup

The contractor is responsible for cleanup of the construction site. All paper bags, wire clippings, must be disposed of as directed. Paper bags, wire clippings and other waste will not be put in bell holes or anodes excavation.

3.7.2 Training

3.7.2.1 Instruction to Government Personnel

During the warranty testing or at a time designated by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager, make available the services of a technician regularly employed or authorized by the manufacturer of the Cathodic Protection System for instructing government personnel in the proper operation, maintenance, safety, and emergency procedures of the Cathodic Protection System. The period of instruction must be not less than two hours and not more than two 8-hour working days. Conduct the training at the jobsite or at another location mutually satisfactory to the government and the contractor. The field instructions will cover all of the items contained

in the operation and maintenance manual.

-- End of Section --

SECTION 26 51 00

INTERIOR LIGHTING
05/20, CHG 2: 11/21

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM A580/A580M	(2023) Standard Specification for Stainless Steel Wire
ASTM A641/A641M	(2019) Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire
ASTM A653/A653M	(2023) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A1008/A1008M	(2023) Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable
ASTM B164	(2003; R 2014) Standard Specification for Nickel-Copper Alloy Rod, Bar, and Wire
ASTM B633	(2023) Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
ASTM D4674 REV A	(2002; R 2010) Standard Practice for Accelerated Testing for Color Stability of Plastics Exposed to Indoor Office Environments

CALIFORNIA ENERGY COMMISSION (CEC)

CEC Title 20	(2019) Appliance Efficiency Regulations / Public Utilities and Energy Division 2. State Energy Resources Conservation and Development Commission
CEC Title 24	(2016) Building Energy Efficiency Standards For Residential and Nonresidential Buildings

EUROPEAN UNION (EU)

Directive 2011/65/EU	(2011) Restriction of the Use of Certain
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Hazardous Substances in Electrical and
Electronic Equipment

ILLUMINATING ENGINEERING SOCIETY (IES)

ANSI/IES LM-79	(2019) Approved Method: Electrical and Photometric Measurements of Solid State Lighting Products
ANSI/IES LM-80	(2020) Approved Method: Measuring Luminous Flux and Color Maintenance of LED Packages, Arrays and Modules
ANSI/IES LS-1	(2020) Lighting Science: Nomenclature and Definitions for Illuminating Engineering
ANSI/IES TM-15	(2020) Technical Memorandum: Luminaire Classification System for Outdoor Luminaires
ANSI/IES TM-21	(2021) Technical Memorandum: Projecting Long-Term Luminous, Photon, and Radiant Flux Maintenance of LED Light Sources
ANSI/IES TM-30	(2020) Technical Memorandum: IES Method for Evaluating Light Source Color Rendition
IES Lighting Library	IES Lighting Library

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 100	(2000; Archived) The Authoritative Dictionary of IEEE Standards Terms
IEEE C2	(2023) National Electrical Safety Code
IEEE C62.41	(1991; R 1995) Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 77	(2017) Temporal Light Artifacts: Test Methods and Guidance for Acceptance Criteria
NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ANSLG C78.377	(2017) Electric Lamps- Specifications for the Chromaticity of Solid State Lighting Products
NEMA C82.77-10	(2020) Harmonic Emission Limits - Related Power Quality Requirements
NEMA ICS 2	(2000; R 2020) Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 V

NEMA ICS 6 (1993; R 2016) Industrial Control and Systems: Enclosures

NEMA SSL 1 (2016) Electronic Drivers for LED Devices, Arrays, or Systems

NEMA SSL 3 (2011) High-Power White LED Binning for General Illumination

NEMA SSL 7A (2015) Phase-Cut Dimming for Solid State Lighting: Basic Compatibility

NEMA WD 1 (1999; R 2020) Standard for General Color Requirements for Wiring Devices

NEMA WD 7 (2011; R 2016; R 2021) Occupancy Motion Sensors Standard

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code

NFPA 101 (2021; TIA 21-1) Life Safety Code

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

47 CFR 15 Radio Frequency Devices

UNDERWRITERS LABORATORIES (UL)

UL 20 (2018; Reprint May 2023) UL Standard for Safety General-Use Snap Switches

UL 94 (2023; Reprint Jan 2024) UL Standard for Safety Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 508 (2018; Reprint Jul 2021) UL Standard for Safety Industrial Control Equipment

UL 844 (2012; Reprint Oct 2021) UL Standard for Safety Luminaires for Use in Hazardous (Classified) Locations

UL 916 (2015; Reprint Oct 2021) UL Standard for Safety Energy Management Equipment

UL 924 (2016; Reprint Dec 2022) UL Standard for Safety Emergency Lighting and Power Equipment

UL 1472 (2015) UL Standard for Safety Solid-State Dimming Controls

UL 1598 (2021; Reprint Jan 2024) UL Standard for Safety Luminaires

- UL 2043 (2023) Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces
- UL 8750 (2015; Reprint Sep 2021) UL Standard for Safety Light Emitting Diode (LED) Equipment for Use in Lighting Products

1.2 DEFINITIONS

- a. Unless otherwise specified or indicated, electrical and electronics terms used in these specifications and on the drawings, must be as defined in IEEE 100 and ANSI/IES LS-1.
- b. For LED luminaire light sources, "Useful Life" is the operating hours before reaching 70 percent of the initial rated lumen output (L70) with no catastrophic failures under normal operating conditions. This is also known as 70 percent "Rated Lumen Maintenance Life" as defined in ANSI/IES LM-80.
- c. For LED luminaires, "Luminaire Efficacy" (LE) is the appropriate measure of energy efficiency, measured in lumens/watt. This is gathered from LM-79 data for the luminaire, in which absolute photometry is used to measure the lumen output of the luminaire as one entity, not the source separately and then the source and housing together.
- d. Total harmonic distortion (THD) is the root mean square (RMS) of all the harmonic components divided by the total fundamental current.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

- Luminaire Drawings; G
- Occupancy/Vacancy Sensor Coverage Layout; G; S
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1.4 QUALITY ASSURANCE

Data, drawings, and reports must employ the terminology, classifications and methods prescribed by the IES Lighting Library as applicable, for the lighting system specified.

1.4.1 Luminaire Drawings

Include dimensions, accessories installation details, and construction details. Photometric data, including CRI, CCT, LED driver type, aiming diagram, zonal lumen data, and candlepower distribution data must accompany shop drawings.

1.4.2 Luminaire Design Data

- a. Provide safety certification and file number for the luminaire family that must be listed, labeled, or identified in accordance with the NFPA 70. Applicable testing bodies are determined by the US Occupational Safety Health Administration (OSHA) as Nationally Recognized Testing Laboratories (NRTL) and include: CSA (Canadian Standards Association), ETL (Edison Testing Laboratory), and UL (Underwriters Laboratories).
- b. Provide long term lumen maintenance projections for each LED luminaire in accordance with ANSI/IES TM-21. Data used for projections must be obtained from testing in accordance with ANSI/IES LM-80.

1.4.3 ANSI/IES LM-79 Test Report

Submit test report on manufacturer's standard production model of specified luminaire. Testing must be performed at the same operating drive current as specified luminaire. Include all applicable and required data in IES format as outlined under "14.0 Test Report" in ANSI/IES LM-79.

1.4.4 ANSI/IES LM-80 Test Report

Submit report on manufacturer's standard production LED light source (package, array, or module) of specified luminaire. Testing must be performed at the same operating drive current as specified luminaire. Include all applicable and required data as outlined under "8.0 Test Report" in ANSI/IES LM-80.

1.4.5 ANSI/IES TM-21 Test Report

Submit test report on manufacturer's standard production LED light source (package, array, or module) of specified luminaire. Testing must be performed at the same operating drive current as specified luminaire. Include all applicable and required data, as well as required interpolation information as outlined under "7.0 Report" in ANSI/IES TM-21.

1.4.6 ANSI/IES TM-30 Test Report

Submit color vector graphic in accordance with ANSI/IES TM-30 on manufacturer's standard production LED light source (package, array, or module) of specified luminaire. Include spectral distribution of test LED light source.

1.4.7 LED Driver and Dimming Switch Compatibility Certificate

Submit certification from the luminaire, driver, or dimmer switch manufacturer that ensures compatibility and operability between devices without flickering and to specified dimming levels.

1.4.8 Photometric Plan

1.4.8.1 Computer-generated Photometric Plans

Computer-generated photometric plans for each space are required to verify proposed luminaires and locations meet the required performance criteria of the design using the applicable light loss factor (LLF).

Target illumination levels are provided for each Interior Application. Depending on the application and the recommendations provided by the IES, values are given as one of the following:

- a. Minimum: No values anywhere on the calculation grid may be less than this value, within a 10 percent margin of error.
- b. Minimum Average: An average, taken over the entire task area for the application, may not be less than this value, within a 10 percent margin of error.
- c. Maximum: No values anywhere on the calculation grid may be greater than this value, within a 10 percent margin of error.
- d. Maximum Average: An average, taken over the entire task area for the application, may not be greater than this value, within a 10 percent margin of error.
- e. Uniformity: Unless otherwise noted, uniformity is calculated as a ratio of the average calculated illuminance over the minimum calculated illuminance of the calculation grid.

1.4.8.2 Schematic Photometric Plan Calculations

Schematic photometric plan calculations must include:

- a. Horizontal illuminance measurements at workplane or other designated height above finished floor, taken at a maximum of every one foot across the task area.
- b. Average maintained illuminance level.
- c. Minimum and maximum maintained illuminance levels.
- d. Lighting power density (Watts per square foot).
- e. LLF. Recommended LLF is 0.81 for LED luminaires but LLF varies based on environment and application.

1.4.8.3 Final Photometric Plan Calculations

Final photometric plan calculations must include:

- a. Horizontal illuminance measurements at workplane or other designated

height above finished floor, taken at a maximum of every one foot across the task area.

- b. Where applicable, vertical illuminance measurements at designated surface, taken at a maximum of every one foot across task area.
- c. Minimum and maximum maintained illuminance levels.
- d. Average maintained illuminance level.
- e. Average to minimum and maximum to minimum ratios for horizontal illuminance.
- f. Lighting power density (Watts per square foot).
- g. LLF. Recommended LLF is 0.81 for LED luminaires but LLF varies based on environment and application.

1.4.9 Occupancy/Vacancy Sensor Coverage Layout

Provide floor plans showing coverage layouts of all devices using manufacturer's product information.

1.4.10 Test Laboratories

Test laboratories for the ANSI/IES LM-79 and ANSI/IES LM-80 test reports must be one of the following:

- a. National Voluntary Laboratory Accreditation Program (NVLAP) accredited for solid-state lighting testing as part of the Energy-Efficient Lighting Products laboratory accreditation program for both LM-79 and LM-80 testing.
- b. One of the qualified labs listed on the Department of Energy - LED Lighting Facts Approved Testing Laboratories List for LM-79 testing.
- c. One of the EPA-Recognized Laboratories listed for LM-80 testing.

1.4.11 Regulatory Requirements

Equipment, materials, installation, and workmanship must be in accordance with the mandatory and advisory provisions of NFPA 70, unless more stringent requirements are specified or indicated. Provide luminaires and assembled components that are approved by and bear the label of UL for the applicable location and conditions unless otherwise specified.

1.4.12 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design, and workmanship. Products must have been in satisfactory commercial or industrial use for six months prior to bid opening. The six-month period must include applications of equipment and materials under similar circumstances and of similar size. The product must have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the six-month period. Where two or more items of the same class of equipment are required, these items must be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated

in this section.

1.4.12.1 Alternative Qualifications

Products having less than a six-month field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.4.12.2 Material and Equipment Manufacturing Date

Do not use products manufactured more than six months prior to date of delivery to site, unless specified otherwise.

1.5 WARRANTY

Support all equipment items by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

1.5.1 Luminaire Warranty

Provide and transfer to the government the original LED luminaire manufacturers standard commercial warranty for each different luminaire manufacturer used in the project.

- a. Provide a written five year minimum replacement warranty for material, luminaire finish, and workmanship. Provide written warranty document that contains all warranty processing information needed, including customer service point of contact, whether or not a return authorization number is required, return shipping information, and closest return location to the luminaire location.
 - (1) Finish warranty must include failure and substantial deterioration such as blistering, cracking, peeling, chalking, or fading.
 - (2) Material warranty must include:
 - (a) All LED drivers and integral control equipment.
 - (b) Replacement when more than 15 percent of LED sources in any lightbar or subassembly(s) are defective, non-starting, or operating below 70 percent of specified lumen output.
 - (c) Replacement when more than 15 percent of LED sources in any lightbar or subassembly(s) show a color shift greater than 0.003 delta u'v' from the zero hour measurement stated in the ANSI/IES LM-79 Test Report.
- b. Warranty period must begin in accordance with the manufacturer's standard warranty starting date.
- c. Provide replacements that are promptly shipped, without charge, to the using Government facility point of contact and that are identical to or an improvement upon the original equipment. All replacements must include testing of new components and assembly.

1.5.2 Lighting Controls Warranty

Provide and transfer to the government the original lighting controls manufacturers standard commercial warranty for each different lighting controls manufacturer used in the project. Warranty coverage must begin from date of final system commissioning or three months from date of delivery, whichever is the earliest. Warranty service must be performed by a factory-trained engineer or technician.

- a. Unless otherwise noted, provide a written five year minimum warranty on the complete system for all systems with factory commissioning. Provide warranty that covers 100 percent of the cost of any replacement parts and services required over the five years which are directly attributable to the product failure. Failures include, but are not limited to, the following:
 - (1) Software: Failure of input/output to execute switching or dimming commands.
 - (2) Damage of electronic components due to transient voltage surges.
 - (3) Failure of control devices, including but not limited to occupancy sensors, photosensors, and manual wall station control devices.
- b. Provide a written five year minimum warranty on all input devices against defect in workmanship or materials provided by device manufacturer.
- c. Provide a written five year minimum warranty on all control components attached to luminaires against defect in workmanship or materials.

1.6 OPERATION AND MAINTENANCE MANUALS

1.6.1 Lighting System

Provide operation and maintenance manuals for the lighting system in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA that provide basic data relating to the design, operation, and maintenance of the lighting system for the building. Include the following:

- a. Manufacturers' operating and maintenance manuals.
- b. Luminaire shop drawings for modified and custom luminaires.
- c. Luminaire Manufacturers' standard commercial warranty information as specified in paragraph LUMINAIRE WARRANTY.

1.6.2 Lighting Control System

Provide operation and maintenance manuals for the lighting control system in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA that provide basic data relating to the design, operation, and maintenance of the lighting control system for the building. Include the following:

- a. Lighting control system layout and wiring plan.
- b. Lighting control system one-line diagram.
- c. Product data for all devices, including installation and programming

instructions.

- d. Occupancy/vacancy sensor coverage layout.
- e. Training materials, such as videos or in-depth manuals, that cover basic operation of the lighting control system and instructions on modifying the lighting control system. Training materials must include calibration, adjustment, troubleshooting, maintenance, repair, and replacement.
- f. Sequence of operation descriptions for each typical room type, including final programming, schedules, and calibration settings.
- g. "As-built" lighting control panel schedules.

PART 2 PRODUCTS

2.1 PRODUCT COORDINATION

2.2 LUMINAIRES

UL 1598, NEMA C82.77-10. Provide luminaires as indicated in the luminaire schedule and NL plates or details on project plans, complete with light source, wattage, and lumen output indicated. All luminaires of the same type must be provided by the same manufacturer. Luminaires must be specifically designed for use with the driver and light source provided.

2.2.1 Luminaires

UL 8750, ANSI/IES LM-79, ANSI/IES LM-80. For all luminaires, provide:

- a. Complete system with LED drivers and light sources.
- b. Housings constructed of non-corrosive materials. All new aluminum housings must be anodized or powder-coated. All new steel housings must be treated to be corrosion resistant.
- c. ANSI/IES TM-21, ANSI/IES LM-80. Minimum L70 lumen maintenance value of 50,000 hours unless otherwise indicated in the luminaire schedule. Luminaire drive current value must be identical to that provided by test data for luminaire in question.
- d. Minimum efficacy as specified in the luminaire schedule. Theoretical models of initial lamp lumens per watt are not acceptable. If efficacy values are not listed in the luminaire schedule, provide luminaires that meet the following minimum values:

Luminaire Style	Minimum Luminaire Efficacy
Recessed 1 by 4, 2 by 4, and 2 by 2	100 LPW
Recessed Downlight (fixed, adjustable, wallwash)	80 LPW
Linear, Accent (undercabinet, cove)	45 LPW
Linear, Ambient (indirect wall mount, linear pendent)	100 LPW

Luminaire Style	Minimum Luminaire Efficacy
High Bay, Low Bay, and Industrial Locations	100 LPW
Food Service and Hazardous Locations	60 LPW
Other (track, residential diffusers)	50 LPW
Exterior Wall Sconce	50 LPW
Steplight	30 LPW
Parking Garage Luminaire	100 LPW

- e. UL listed for dry or damp location typical of interior installations. Any luminaire mounted on the exterior of the building must be UL listed for wet location typical of exterior installations.
- f. LED driver and light source package, array, or module are accessible for service or replacement without removal or destruction of luminaire.
- g. Lenses constructed of heat tempered borosilicate glass, UV-resistant acrylic, or silicone. Provide polycarbonate vandal-resistant lenses as indicated. Sandblasting, etching and polishing must be performed as indicated in the luminaire description.
- h. ANSI/IES TM-15. Provide exterior building-mounted luminaires that do not exceed the BUG ratings as listed in the luminaire schedule. If BUG ratings are not listed in the luminaire schedule, provide luminaires that meet the following minimum values for each application and mounting conditions:

Lighting Application	Mounting Conditions	BUG Rating
Exterior Wall Sconce	Above 4 feet AFF	B1-U0-G2
Exterior Wall Sconce	Below or at 4 feet AFF	B4-U0-G4
Steplight	Above 4 feet AFF	B1-U1-G2
Steplight	Below or at 4 feet AFF	B4-U1-G4
Parking Garage Luminaire	Ceiling mounted	B4-U4-G3

2.2.2 Luminaires for Hazardous Locations

In addition to requirements stated herein, provide LED luminaires for hazardous locations which conform to UL 844 or which have Factory Mutual certification for the class and division indicated.

2.3 LIGHT SOURCES

NEMA ANSLG C78.377, NEMA SSL 3. Provide type, delivered lumen output, and wattage as indicated in the luminaire schedule on project plans.

2.3.1 LED Light Sources

Provide LED light sources that meet the following requirements:

- a. NEMA ANSLG C78.377. Emit white light and have a nominal CCT of 3500 Kelvin.
- b. Minimum Color Rendering Index (CRI) of 80.
- c. Directive 2011/65/EU. Restriction of Hazardous Substances (RoHS) compliant.
- d. Light source color consistency by utilizing a binning tolerance within a 3-step McAdam ellipse.

2.4 LED DRIVERS

NEMA SSL 1, UL 8750. Provide LED drivers that are electronic, UL Class 1 or Class 2, constant-current type and that comply with the following requirements:

- a. The combined driver and LED light source system does not exceed the minimum luminaire efficacy values as listed in the luminaire schedule provided.
- b. Operates at a voltage of 120-277 volts at 50/60 hertz, with input voltage fluctuations of plus/minus 10 percent.
- c. Power Factor (PF) greater than or equal to 0.90 at full input power and across specified dimming range.
- d. Maximum Total Harmonic Distortion (THD) less than 20 percent at full input power and across specified dimming range.
- e. Operates for at least 50,000 hours at maximum case temperature and 90 percent non-condensing relative humidity.
- f. Withstands Category A surges of 2 kV without impairment of performance. Provide surge protection that is integral to the driver.
- g. Integral thermal protection that reduces the output power to protect the driver and light source from damage if the case temperature approaches or exceeds the driver's maximum operating temperature.
- h. 47 CFR 15. Complies with the requirements of the Federal Communications Commission (FCC) rules and regulations, Non-Consumer (Class A) for EMI/RFI (conducted and radiated).
- i. Class A sound rating.
- j. Directive 2011/65/EU. Restriction of Hazardous Substances (RoHS) compliant.
- k. Provide dimming capability as indicated in the luminaire schedule on project plans. Dimmable drivers must dim down to 10 percent. Dimmable drivers must be controlled by a Class 2 low voltage 0-10VDC controller dimming signal protocol unless otherwise specified. LED drivers of the same family/series must track evenly across multiple

luminaires at all light levels.

2.5 LIGHTING CONTROLS

Provide network certification for all networked lighting control systems and devices in accordance with the requirements of Section 25 05 11.01 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS. Provide lighting control systems that do not switch off battery-operated or emergency backup luminaires or exit signs in path of egress. Provide system with override of lighting control devices controlling luminaires in path of egress with activation of fire alarm system.

2.5.1 System

Provide lighting control system that operates the lighting system as described in the lighting control strategies in the project plans. Submit Sequence of Operation for Lighting Control System describing the operation of the proposed lighting control system and devices. Sequence of Operation must provide the strategies identified in the lighting control strategies.

2.5.1.1 Localized Control Systems

Provide room or area-wide lighting control system capable of manual control, time-based control, and receiving input from photosensors and occupancy/vacancy sensors.

2.5.1.1.1 Local Area Controller

Provide controller designed for single area or room with the following requirements:

- a. Operates at a voltage of 120-277 volts at 50/60 hertz.
- b. Multi-zone, with 1 relay rated 20 amps each with one manual dimmer per zone.
- c. Provide inputs for occupancy/vacancy sensors, photosensors, and low-voltage wall switches.
- d. Provide daylight harvesting capability with full-range dimming control with input from photosensor.
- e. Provide capability for receptacle load control from occupancy sensors.
- g. Capable of 0-10V dimming.
- h. AV interface via ethernet and CAT5.
- i. Provide override 'ON' function with input from Fire Alarm Control Panel for all emergency lighting. Controller must not turn off power to emergency batteries or exit signs.

2.5.1.2 Centralized Control Systems

Provide a centralized lighting control system capable of manual control, time-based control, receiving input from photosensors and occupancy/vacancy sensors, with the capabilities of controlling, monitoring, and programming changes from one centralized on-site location,

and integration with other building systems.

2.5.1.2.1 Lighting Control Panel

UL 916, 47 CFR 15. Provide an electronic, programmable lighting control panel complete with microprocessor, capable of providing lighting control with input from internal programming, digital switches, time clocks, and other control devices.

Enclose panel hardware in a surface-mounted, NEMA 4, painted, steel enclosure with lockable access door and ventilation openings. Internal low-voltage compartment must be separated from line-voltage compartment of enclosure with only low-voltage compartment accessible upon opening of door. Provide additional remote cabinets that communicate back to main control panel as required. Provide Lighting Control Panels that meet the following criteria:

- a. Input voltage of 120-277 at 50/60 Hz, with internal low-voltage VDC power supply as required.
- b. Solid-state, microprocessor-based, internal astronomical time clock. Microprocessor must have nonvolatile memory and must reset automatically after power interruptions of up to 90 days.
- c. Interface for providing local programming and control capability, with physical key-locked cover or programmed security access code to prevent unauthorized use.
- d. Dimming modules capable of 0-10V dimming.
- e. Modules and control panels include multichannel output with multiple inputs for manual control, photosensors, and occupancy/vacancy sensors.
- g. Outputs that require line-voltage switching are provided by relays which are designed for 10 years of use at full rated load.

2.5.1.2.2 Lighting Contactor

NEMA ICS 2, NEMA ICS 6. Provide an electrically-held lighting contactor housed in a NEMA 4X enclosure. Provide contactor with one normally closed(NC), single pole contacts, rated 600 volts, 30 amps. Provide coil operating voltage of 277 volts.

2.5.2 Devices

2.5.2.1 Switches

Provide line-voltage toggle switches as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. When used for non-digital loads, devices must be rated at 20 Amps inductive load, and be compatible with the lighting control systems.

2.5.2.2 Digital Switch Timers

Provide line-voltage toggle switches that allow manual control to ON and automatically switches lighting load to OFF. Device operates with the use of paddle, button, or toggle, and operates at 120-277 volts. Device allows for programming of auto off timer from 5 minutes to 12 hours.

2.5.2.3 Wall Box Dimmers

UL 1472, UL 20, IEEE C62.41, NEMA 77, NEMA SSL 7A. Dimmers must provide flicker-free, continuously variable light output throughout the dimming range of 10 percent to 100 percent. Devices must be capable of operating at their full rated capacity regardless of being single or ganged-mounted, and be compatible with three-way and four-way switching scenarios.

Provide wall-box dimmers that meet the following requirements:

- a. Device operates as an independent control device.
- b. Device operates with the use of a vertical slider, paddle, rotary, button, or toggle with adjacent vertical slider.
- c. Finish of device matches switches and outlets in the same area.
- d. Back box in wall has sufficient depth to accommodate body of switch and wiring.
- e. Dimmer is capable of controlling 0-10 volt LED drivers. Dimmers and the drivers they control must be provided from the same manufacturer or tested and certified as compatible for use together.
- f. Radio frequency interference suppression is integral to device.

2.5.2.4 Occupancy/Vacancy Sensors

IEEE C62.41, NEMA WD 1, UL 94, UL 916, UL 508, ASTM D4674 REV A, NEMA WD 7. Provide occupancy/vacancy sensors with coverage patterns as indicated on project plans. Provide no less quantity of sensors as shown on plans, but add additional sensors when required to fulfill coverage requirement for the specific model of sensor provided. Provide sensor types as described in the sequence of operations. Sensor locations and quantities are shown in shop drawings provided by the lighting control system manufacturer. Provide occupancy sensor operation that requires movement to activate luminaires controlled and turns luminaires off after a set time of inactivity. Provide ceiling or wall-mounted occupancy/vacancy sensors that meet the following requirements:

- a. Operating voltage of 120-277volts.
- b. Time delay of 30 seconds to 30 minutes with at least four intermediate time delay settings.
- c. Sensors are ceiling mounted or wall mounted.
- d. Does not exceed a maximum load requirement of 20mA at 24VDC. No minimum load requirement and be capable of switching from zero to 800 W at 120 VAC, 50/60 Hz and from zero to 1200 W at 277 VAC, 50/60 Hz.
- e. Shielded or controlled by internal logic to adjust sensitivity to avoid false triggering due to ambient temperature, air temperature variations or HVAC air movement.
- f. Sensor is equipped to automatically energize the connected load upon loss of normal power when located in a means of egress.
- g. Occupancy and vacancy operation is field-adjustable and programmable

via lighting control system processor, or programmable with push-button or dip switch on the sensor device.

- h. No leakage current to load when in the off mode.
- i. Utilize zero-crossing circuitry to prevent damage from high inrush current and to promote long life operation.

2.5.2.4.1 Passive Infrared Sensors

Provide Passive Infrared Sensors (PIR) sensors that detect occupancy by sensing heat and movement in the area of coverage. Provide sensors are constructed of a housing of high-impact, injection-molded thermoplastic. Provide PIR sensors that are temperature compensated, with a dual element sensor and a multi-element fresnel lens of POLY IR4 material.

2.5.2.4.2 Ultrasonic Sensors

Provide ultrasonic sensors that detect occupancy by sensing a change in pattern of reflected ultrasonic waves in the area of coverage. Provide sensors that are constructed of a housing of high-impact, injection-molded thermoplastic. Provide ultrasonic sensors that operate at 40 kHz.

2.5.2.4.3 Dual Technology Sensors

Provide dual technology sensors that meet the requirements for PIR sensors and ultrasonic sensors indicated above. If either the PIR or ultrasonic sensing registers occupancy, the luminaires must remain on.

2.5.2.4.4 High Bay Sensors

Provide occupancy/vacancy sensors specifically designed for high-bay mounting applications for all ceiling-mounted sensors mounted above 35 feet using PIR technology. Provide high-bay sensors with interchangeable lenses for 360 degree open area coverage or narrow rectangular warehouse aisle coverage.

2.5.2.4.5 Power Packs

UL 2043. Provide power packs to provide power to lighting control sensors as required in accordance with the manufacturer's specifications. Provide power packs that meet the following requirements:

- a. Operate at an input voltage of 120-277 VAC, with an output voltage 12-24 VDC at 225 mA.
- b. Constructed of plenum-rated, high-impact thermoplastic enclosure.
- c. Utilizes zero-crossing circuitry to prevent damage from inrush current.
- d. Maximum load rating of 16 amps for electronic lighting loads.
- e. Directive 2011/65/EU. Restriction of Hazardous Substances (RoHS) compliant.

2.5.2.5 Photosensors

CEC Title 24, CEC Title 20. Provide photosensors that meet the following requirements:

- a. Detect changes in ambient lighting level and enable dimming as required by sequence of operation by operating in an open-loop system.
- b. Contain a detection cone, where the base of the cone may be circular or an elongated shape, and where the smallest angle between the edge and the axis of the cone is between 20 and 50 degrees. The cone axis may be tilted to the vertical when installed to give the sensor preferred directionality.
- c. Sensors are ceiling-mounted with sensitivity, filtering, range and viewing angle to meet requirements of sequence of operation, scope of work and construction documents.
- d. Time delay that is adjustable from 1 to 30 seconds ON delay, and 1 to 30 minutes OFF delay to prevent cycling, with deadband adjustment of 25 percent to 100 percent above lower setpoint.
- e. Output dimming signal is linear to light level with less than 1 percent variation. Cadmium sulfide photo-resistors are not acceptable.
- f. Sensor is not combined in the same housing or location with occupancy or vacancy sensors if the proper location for one function compromises the successful operation of the other function, or in any way reduces the system's ability to meet the design intent.

2.6 EXIT AND EMERGENCY LIGHTING EQUIPMENT

2.6.1 Exit Signs

UL 924, NFPA 101. Provide wattage as indicated in the luminaire schedule on project plans. Provide LED Exit Signs that meet the following criteria:

- a. UL listed for damp location.
- b. Configured for universal mounting.
- c. 6 inch high, 3/4 inch stroke red lettering on face of sign with chevrons on either side of lettering to indicate direction.
- d. Single or double face as indicated in project plans and luminaire schedule.

2.6.1.1 Exit Signs with Battery Backup

Equip with automatic power failure device, test switch, and pilot light, and fully automatic high/low trickle charger in a self-contained power pack. Battery must be sealed, maintenance free nickel-cadmium type, and must operate unattended for a period of not less than five years. Emergency run time must be a minimum of 1-1/2 hours. LEDs must have a minimum rated life of 10 years. Provide self-diagnostic circuitry integral to emergency LED driver.

2.6.1.2 Remote-Powered Exit Signs

Provide exit sign that contains provision for 120-277 VAC input from remote source.

2.6.2 Emergency Lighting Unit (ELU)

UL 924, NFPA 101. Provide emergency lighting units (ELUs) completely assembled with wiring and mounting devices, ready for installation at the locations indicated. Provide in UV-stable, thermo-plastic housing with UL damp label as indicated. Emergency lighting units must be rated for 12 volts, except units having no remote-mounted light sources and having no more than two unit-mounted light sources may be rated six volts. Equip units with brown-out sensitive circuit to activate battery when input voltage falls to 75 percent of normal. Equip with two LED light sources, automatic power failure device, test switch, and pilot light, and fully automatic high/low trickle charger in a self-contained power pack. Battery must be sealed, maintenance free lead-calcium or nickel-cadmium type, and must operate unattended for a period of not less than five years. Emergency run time must be a minimum of 90 minutes. LEDs must have a minimum rated life of 10 years. Provide self-diagnostic circuitry integral to emergency LED driver.

2.6.3 LED Emergency Drivers

UL 924, NFPA 101. Provide LED emergency driver with automatic power failure detection, test switch and LED indicator (or combination switch/indicator) located on luminaire exterior, and fully-automatic solid-state charger, battery and inverter integral to a self-contained housing. Provide self-diagnostic function integral to emergency driver. Integral nickel-cadmium or lead-calcium battery is required to supply a minimum of 90 minutes of emergency power at 10watts, 10-50 VDC, constant output. Driver must be RoHS compliant, rated for installation in plenum-rated spaces and damp locations, and be warranted for a minimum of five years.

2.6.4 Self-Diagnostic Circuitry for LED Drivers

UL 924, NFPA 101. Provide emergency lighting unit with fully-automatic, integral self-testing/diagnostic electronic circuitry. Circuitry must provide for a one minute diagnostic test every 28 days, and a 30 minute diagnostic test every six months, minimum. Any malfunction of the unit must be indicated by LED(s) visible from the exterior of the luminaire. A manual test switch must also be provided to perform a diagnostic test at any given time.

2.7 LUMINAIRE MOUNTING ACCESSORIES

2.7.1 Suspended Luminaires

- a. Provide hangers capable of supporting twice the combined weight of luminaires supported by hangers.
- b. Hangers must allow luminaires to swing within an angle of 45 degrees. Brace pendants 4 feet or longer to limit swinging.
- c. Single-unit suspended luminaires must have twin-stem hangers. Multiple-unit or continuous row luminaires with a separate power supply cord must have a tubing or stem for wiring at one point and a tubing or rod suspension provided for each unit length of chassis, including one at each end.
- d. Provide all linear pendent and surface mounted luminaires with two supports per four-foot section or three per eight-foot section unless

otherwise recommended by manufacturer.

- e. Provide rods in minimum 0.18 inch diameter.

2.7.2 Recess and Surface Mounted Luminaires

Provide access to light source and LED driver from bottom of luminaire. Provide trim and lenses for the exposed surface of flush-mounted luminaires as indicated on project drawings and specifications. Luminaires recessed in ceilings which have a fire resistive rating of one hour or more must be enclosed in a box which has a fire resistive rating equal to that of the ceiling. For surface mounted luminaires with brackets, provide flanged metal stem attached to outlet box, with threaded end suitable for supporting the luminaire rigidly in design position. Flanged part of luminaire stud must be of broad base type, secured to outlet box at not fewer than three points.

2.7.3 Luminaire Support Hardware

2.7.3.1 Wire

ASTM A641/A641M. Galvanized, soft tempered steel, minimum 0.11 inches in diameter, or galvanized, braided steel, minimum 0.08 inches in diameter.

2.7.3.2 Wire for Humid Spaces

ASTM A580/A580M. Composition 302 or 304, annealed stainless steel, minimum 0.11 inches in diameter.

ASTM B164. UNS NO4400, annealed nickel-copper alloy, minimum 0.11 inches in diameter.

2.7.3.3 Threaded Rods

Threaded steel rods, 3/16 inch diameter, zinc or cadmium coated.

2.7.3.4 Straps

Galvanized steel, one by 3/16 inch, conforming to ASTM A653/A653M, with a light commercial zinc coating or ASTM A1008/A1008M with an electrodeposited zinc coating conforming to ASTM B633, Type RS.

2.7.4 Power Hook Luminaire Hangers

UL 1598. Provide an assembly consisting of through-wired power hook housing, interlocking plug and receptacle, power cord, and luminaire support loop. Power hook housing must be cast aluminum having two 3/4 inch threaded hubs. Support hook must have safety screw. Luminaire support loop must be cast aluminum with provisions for accepting 3/4 inch threaded stems. Power cord must include 16 inches of 3 conductor No. 16 Type SO cord. Assembly must be rated 120 volts or 277 volts, 15 amperes.

2.8 EQUIPMENT IDENTIFICATION

2.8.1 Manufacturer's Nameplate

Each item of equipment must have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be

acceptable.

2.8.2 Labels

UL 1598. All luminaires must be clearly marked for operation of specific light sources and LED drivers. The labels must be easy to read when standing next to the equipment, and durable to match the life of the equipment to which they are attached. Note the following light source characteristics in the format "Use Only _____":

- a. Correlated Color Temperature (CCT) and Color Rendering Index (CRI) for all luminaires.
- b. Driver and dimming protocol.

All markings related to light source type must be clear and located to be readily visible to service personnel, but unseen from normal viewing angles when light sources are in place. LED drivers must have clear markings indicating dimming type and indicate proper terminals for the various outputs.

2.9 FACTORY APPLIED FINISH

NEMA 250. Provide all luminaires and lighting equipment with factory-applied painting system that as a minimum, meets requirements of corrosion-resistance testing.

PART 3 EXECUTION

3.1 INSTALLATION

IEEE C2, NFPA 70.

3.1.1 Light Sources

When light sources are not provided as an integral part of the luminaire, deliver light sources of the type, wattage, lumen output, color temperature (CCT), color rendering index (CRI), and voltage rating indicated to the project site and install just prior to project completion, if not already installed in the luminaires from the factory.

3.1.2 Luminaires

Set luminaires plumb, square, and level with ceiling and walls, in alignment with adjacent luminaires and secure in accordance with manufacturers' directions and approved drawings. Provide accessories as required for ceiling construction type indicated on Finish Schedule. Luminaire catalog numbers do not necessarily denote specific mounting accessories for type of ceiling in which a luminaire may be installed. Provide wires, straps, or rods for luminaire support in this section. Install luminaires with vent holes free of air blocking obstacles.

3.1.2.1 Suspended Luminaires

Measure mounting heights from the bottom of the luminaire for ceiling-mounted luminaires and to center of luminaire for wall-mounted luminaires. Obtain architect approval of the exact mounting height on the job before commencing installation and, where applicable, after coordinating with the type, style, and pattern of the ceiling being

installed. Support suspended luminaires from structural framework of ceiling or from inserts cast into slab.

- a. Provide suspended luminaires with 45 degree swivel hangers so that they hang plumb and level.
- b. Locate so that there are no obstructions within the 45 degree range in all directions.
- c. The stem, canopy and luminaire must be capable of 45 degree swing.
- d. Rigid pendent stem, aircraft cable, rods, or chains 4 feet or longer excluding luminaire must be braced to prevent swaying using three cables at 120 degree separation.
- e. Suspended luminaires in continuous rows must have internal wireway systems for end to end wiring and must be properly aligned to provide a straight and continuous row without bends, gaps, light leaks or filler pieces.
- f. Utilize aligning splines on extruded aluminum luminaires to assure minimal hairline joints.
- g. Support steel luminaires to prevent "oil-canning" effects.
- h. Match supporting pendants with supported luminaire. Aircraft cable must be stainless steel.
- i. Match finish of canopies to match the ceiling, and provide low profile canopies unless otherwise shown.
- j. Maximum distance between suspension points must be 10 feet or as recommended by the manufacturer, whichever is less.

3.1.2.2 Recessed and Semi-Recessed Luminaires

- a. Support recessed and semi-recessed luminaires independently from the building structure by a minimum of two wires, straps or rods per luminaire and located near opposite corners of the luminaire. Secure horizontal movement with clips provided by manufacturer. Ceiling grid clips are not allowed as an alternative to independently supported luminaires.
- b. Support round luminaires or luminaires smaller in size than the ceiling grid independently from the building structure by a minimum of four wires, straps or rods per luminaire, spaced approximately equidistant around.
- c. Do not support luminaires by acoustical tile ceiling panels.
- d. Where luminaires of sizes less than the ceiling grid are indicated to be centered in the acoustical panel, support each independently and provide at least two 3/4 inch metal channels spanning, and secured to, the ceiling tees for centering and aligning the luminaire.
- e. Luminaires installed in suspended ceilings must also comply with the requirements of Section 09 51 00 ACOUSTICAL CEILINGS.
- f. Adjust aperture rings on all applicable ceiling recessed luminaires to

accommodate various ceiling material thickness. Coordinate cut-out size in ceiling to ensure aperture covers cut-out entirely. Install aperture rings such that the bottom of the ring is flush with finished ceiling or not more than 1/16 inch above. Do not install luminaires such that the aperture ring extends below the finished ceiling surface.

3.1.2.3 Field Applied Painting

Provide painting as specified in Section 09 90 00 PAINTS AND COATINGS.

3.1.3 LED Drivers

Provide LED drivers integral to luminaire as constructed by the manufacturer.

3.1.4 Exit Signs

NFPA 101. Wire exit signs and emergency lighting units ahead of the local switch, to the normal lighting circuit located in the same room or area.

Connect exit signs on separate circuits and serve from a separate circuit breaker. Provide only one source of control, which would be the separate circuit breaker. Paint source of control red and provide lockout capability.

3.1.5 Lighting Controls

Refer to Section 25 05 11.01 CYBERSECURITY FOR FACILITY-RELATED CONTROL SYSTEMS for additional lighting control installation requirements.

3.1.5.1 Occupancy/Vacancy Sensors

- a. Provide quantity of sensor units indicated as a minimum. Provide additional units to give full coverage over controlled area. Full coverage must provide hand and arm motion detection for office and administration type areas and walking motion for industrial areas, warehouses, storage rooms and hallways.
- b. Locate ceiling-mounted sensors no closer than 6 feet from the nearest HVAC supply or return diffuser.
- c. Locate the sensor(s) as indicated and in accordance with the manufacturer's recommendations.

3.1.5.2 Photosensors

Locate and aim sensor as indicated and in accordance with the manufacturer's recommendations. Adjust sensor set-point in accordance with the manufacturer's recommendations and for the indicated light level of the area of coverage, measured at the work plane.

3.2 FIELD QUALITY CONTROL

3.2.1 Tests

3.2.1.1 Lighting Control Verification Tests

Verify lighting control system and devices operate according to approved sequence of operations. Verification tests are to be completed after

commissioning.

- a. Verify occupancy/vacancy sensors operate as described in sequence of operations. Provide testing of sensor coverage, sensitivity, and time-out settings in all spaces where sensors are placed. This is to be completed only after all furnishings have been installed. Submit occupancy/vacancy sensor verification test.
- b. Verify photosensors operate as described in sequence of operations. Provide testing of sensor coverage, aiming, and calibration in all spaces where sensors are placed. This is to be completed only after all furnishings have been installed. Submit photosensor verification test.
- c. Verify wall box dimmers and scene wallstations operate as described in sequence of operations.

3.2.1.2 Emergency Lighting Test

Interrupt power supply to demonstrate proper operation of emergency lighting. If adjustments are made to the lighting system, re-test system to show compliance with standards.

3.3 CLOSEOUT ACTIVITIES

3.3.1 Commissioning

NFPA 101. Commission all components of the lighting system and lighting control system in accordance with Section 01 91 00.15 BUILDING COMMISSIONING. Factory Trained Field Service Technician is responsible for calibration and programming sequences for input devices and systems in accordance with the requirements described in the sequence of operation.

3.3.2 Training

3.3.2.1 Maintenance Staff Training

Submit a Maintenance Staff Training Plan at least 30 calendar days prior to training session that describes training procedures for Owner's personnel in the operation and maintenance of lighting and lighting control system. Provide on-site training which demonstrates full system functionality, assigning schedules, calibration adjustments for light levels and sensor sensitivity, integration procedures for connecting to third-party devices, and manual override including information on appropriate use. Provide protocols for troubleshooting, maintenance, repair, and replacement, and literature on available system updates and process for implementing updates.

3.3.2.2 End-User Training

Submit an End-User Training Plan at least 30 calendar days prior to training session that describes training procedures for end-users on the lighting control system. Provide users with a list of control devices located within user-occupied spaces, such as photosensors and occupancy and vacancy sensors, including information on the proper operation and schedule for each device. Provide demonstration for each type of interface. Provide users with the building schedule as currently commissioned, including conditional programming based on astronomic time clock functionality. Provide users with the correct contact information

for maintenance personnel who will be available to address any lighting control issues.

Provide laminated instructions to the user at each scene wallstation. Provide only instructions relevant to the functionality of the specific scene wallstation. Provide a description of each labeled scene control button. If the room utilizes occupancy/vacancy sensors or photosensors, include a description of this functionality on the instruction sheet.

-- End of Section --

SECTION 27 05 14.00 10

CABLE TELEVISION PREMISES DISTRIBUTION SYSTEM
04/06

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National
Electrical Code

1.2 SUMMARY

Provide a cable TV premises distribution system consisting of coaxial cables and connecting hardware to transport television signals throughout the building to user locations as indicated. Submit detail drawings including a complete list of equipment and material and containing complete wiring and schematic diagrams and other details required to demonstrate that the system has been coordinated and will function properly as a system. Drawings shall include vertical riser diagrams, equipment rack and panel details, elevation drawings of telecommunications closet walls, outlet face plate details for each outlet configuration, and descriptions and types of cables, conduits, and cable trays, if used. Drawings shall show proposed layout and anchorage of equipment and appurtenances, and equipment relationship to other parts of the work including clearance for maintenance and operation.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Cable TV Premises Distribution System; G
Installation; G

SD-03 Product Data

Test Plan; G

Qualifications

SD-06 Test Reports

Testing

SD-07 Certificates

Materials and Equipment

SD-08 Manufacturer's Instructions

Manufacturer's Recommendations

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G

1.4 QUALIFICATIONS

Submit proof of the qualifications of the Contractor, Installers, and Manufacturers that will perform the work, and provide the specified products.

1.4.1 Minimum Contractor Qualifications

Work under this section shall be performed, and equipment shall be furnished and installed, by a qualified Contractor as defined herein. The Contractor shall have a minimum of two years of experience in the installation and testing of coaxial cable-based TV distribution systems and equipment. Installers assigned to the installation of this system or its components shall have a minimum of two years of experience in the installation of the specified coaxial cable and components.

1.4.2 Minimum Manufacturer Qualifications

The equipment and hardware provided under this contract shall be products of manufacturers that have a minimum of two years of experience in producing the types of systems and equipment specified.

1.5 DELIVERY, STORAGE, AND HANDLING

Protect equipment delivered and placed in storage from the weather, humidity and temperature variation, dirt and dust or other contaminants.

1.6 ENVIRONMENTAL REQUIREMENTS

Connecting hardware shall be rated for operation under ambient conditions of 32 to 140 degrees F and in the range of 0 to 95 percent relative humidity, non-condensing.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

Provide materials and equipment which are the standard products of a manufacturer regularly engaged in the manufacture of the products and that are the manufacturer's latest standard design that has been in satisfactory use for at least one year prior to installation. Where materials or equipment are specified to conform, be constructed or tested to meet specific requirements, submit certification that the items provided conform to such requirements. Certification by a nationally recognized testing laboratory that a representative sample has been tested to meet the requirements, or a published catalog specification statement

to the effect that the item meets the referenced standard, is acceptable as evidence that the item conforms. Compliance with these requirements does not relieve the Contractor from compliance with other requirements of the specifications. Materials and equipment shall conform to the respective publications and other requirements specified below and to the applicable requirements of NFPA 70. Cables shall be labeled on both ends with circuit number, room number, or other appropriate marking allowing for correct identification of the cable and its destination. Each faceplate shall be labeled with its function and a unique number to identify the cable run.

2.1.1 Coaxial Cable

Coaxial cable shall be RG-6/U, quad shield. Cable shall be label-verified. Cable jacket shall be factory marked at regular intervals identifying cable type. Cable shall be rated CMP orCMR in accordance with NFPA 70. Interconnecting cables shall be cable assemblies consisting of RG-6/U coaxial cable with male connectors at each end, provided in lengths determined by equipment locations as shown.

2.1.2 Outlets

Cable television outlets, including wall outlet plates, shall be equipped with a female connector to accept the connecting coaxial cable from the user's television set. Faceplates provided shall be ivory impact resistant plastic.

2.1.3 Outlet Boxes

Electrical boxes for cable television outlets shall be 4-11/16 inch square by 2-1/8 inches deep with minimum 3/8 inch deep single gang plaster ring. Conduits shall be minimum 1 inch.

PART 3 EXECUTION

3.1 INSTALLATION

Install system components and appurtenances in accordance with NFPA 70, manufacturer's instructions and as shown. Submit record drawings for the installed cable system showing the locations of cable terminations, including outlets, and location and routing of cables. The identifier for each termination and cable shall appear on the drawings. Provide necessary interconnections, services, and adjustments required for a complete cable television distribution system, ready to connect to external television signal sources. Penetrations in fire-rated construction shall be firestopped in accordance with Section 07 84 00 FIRESTOPPING. Install conduits, outlets, raceways, and wiring in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Cables and outlets shall be individually labeled and marked. Cables shall not be installed in the same cable tray, utility pole compartment, or floor trench compartment with ac power cables. Cables not installed in conduit or wireways shall be properly secured and neat in appearance and, if installed in plenums or other spaces used for environmental air, shall comply with NFPA 70 requirements for this type of installation.

3.1.1 Horizontal Cable Installation

The rated cable pulling tension shall not be exceeded. Cable shall not be stressed such that twisting, stretching or kinking occurs. Cable shall

not be spliced. Cable not in a wireway shall be suspended a minimum of 8 inches above ceilings by cable supports no greater than 60 inches apart. Cable shall not be run through structural members or in contact with pipes, ducts, or other potentially damaging items. Placement of cable parallel to power conductors shall be avoided, if possible; a minimum separation of 12 inches shall be maintained when such placement cannot be avoided. Cables shall be terminated unless shown otherwise. Minimum bending radius shall not be exceeded during installation or once installed. Cable ties shall not be excessively tightened such that the transmission characteristics of the cable are altered.

3.1.2 Riser Cable Installation

The rated cable pulling tension shall not be exceeded. Riser cable support intervals shall be in accordance with manufacturer's recommendations. Where installation procedures, or any part thereof, are required to be in accordance with the recommendations of the manufacturer of the material being installed, printed copies of these recommendations shall be provided prior to installation. Installation of the item will not be allowed to proceed until the recommendations are received and approved. Cable bend radius shall not be less than ten times the outside diameter of the cable during installation and once installed. Maximum tensile strength rating of the cable shall not be exceeded. Cable shall not be spliced.

3.1.3 Cables

Cables shall have a minimum of 6 inches of slack cable loosely coiled into the cable television outlet boxes. Minimum manufacturer's bend radius shall not be exceeded.

3.1.4 Pull Cords

Pull cords shall be installed in conduits serving the cable television premises distribution system which do not initially have cable installed.

3.2 TERMINATIONS

Cables and conductors shall sweep into termination areas; cables and conductors shall not bend at right angles. Manufacturer's minimum bending radius shall not be exceeded. Coaxial cables shall be terminated with appropriate connectors as required. Cable shield conductor shall be grounded to communications ground at only one point and shall not make electrical contact with ground anywhere else.

3.3 GROUNDING

The cable television distribution system ground shall be installed in the cable television entrance facility and in any auxiliary closet identified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM or otherwise indicated. Equipment racks shall be connected to the electrical safety ground.

3.4 TESTING

Submit test reports in booklet form with witness signatures verifying execution of tests. The cable system testing documentation shall include the physical routing and a test report for each cable (end-to-end) from the installed outlet to the main termination point. Test reports shall be submitted within 14 days after completion of testing. Materials and

documentation to be furnished under this specification are subject to inspections and tests.

- a. Submit a Test Plan defining the tests required to ensure that the system meets technical, operational and performance specifications, 60 days prior to the proposed test date. The plan shall be approved before testing begins. The test plan shall identify the capabilities and functions to be tested, and include detailed instructions for the setup and execution of each test and procedures for evaluation and documentation of the results.
- b. Components shall be terminated prior to testing.
- c. Equipment and systems will not be accepted until the required inspections and tests have been made, demonstrating that the cable television premises distribution system conforms to the specified requirements, and that the required equipment, systems, and documentation have been provided.
- d. After installation of the cable and before connecting system components, each cable section shall be end-to-end tested using a time domain reflectometer (TDR) to determine shorts, opens, kinks, and other impedance discontinuities and their locations. Cable sections showing adverse impedance discontinuities (greater than 6 dB loss) shall be replaced at the Contractor's expense.
- e. There shall be no cable splices between system components unless approved by the Government.

3.5 OPERATION AND MAINTENANCE MANUALS

Submit commercial, off-the-shelf manuals for operation, installation, configuration, and maintenance of products provided as a part of the cable television premises distribution system.

-- End of Section --

SECTION 27 05 28.36 40

CABLE TRAYS FOR COMMUNICATIONS SYSTEMS
05/17

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM A123/A123M (2017) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA VE 1 (2017) Metal Cable Tray Systems

NEMA VE 2 (2013; ERTA 2016) Cable Tray Installation Guidelines

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code

1.2 ADMINISTRATIVE REQUIREMENTS

1.2.1 Pre-Installation Meetings

The Contracting Officer will schedule a pre-installation meeting within 30 days of contract award. Submit fabrication drawings for review and approval.

Submit manufacturer's product data for the following items:

- a. Cable Trays
- b. Supports

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Fabrication Drawings; G

Installation Drawings; G

SD-03 Product Data

Cable Trays; G

Supports; G

SD-08 Manufacturer's Instructions

Manufacturer's Instructions

1.4 QUALITY CONTROL

Comply with NEMA VE 1.

Comply with NEC, requirements that apply to the construction and installation of cable tray and cable channel systems (Article 392 NEC).

Provide products that are UL-classified and labeled with the UL classification mark.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

Provide ladder cable trays consisting of two longitudinal side members connected by individual transverse members.

2.2 FABRICATION

Submit fabrication drawings for cable trays. Ensure the drawings contain details showing the fabrication and assembly details performed in the factory.

Before assembly, use an antioxidant compound to coat the contact surfaces of trays. Ensure that the finishes of edges, fittings, and hardware are free from burrs and sharp edges. Include splice and end plates, dropouts, and miscellaneous hardware.

2.3 COMPONENTS

2.3.1 Supports

Permit both vertical and horizontal adjustment, where possible on supports and hangers. Provide an adequate bearing surface for the tray on the horizontal and vertical tray supports, and ensure that the surface can accommodate holddown clamps or fasteners. Provide a means, other than friction, for securely fastening cable trays to supports.

Provide support for cable trays at intervals of no more than 6 . Place

supports for horizontal-elbow tray fittings within 2 of each fitting extremity and as recommended by the cable tray manufacturer.

Ensure that the cable trays can carry at least 150 pounds per linear foot when supported at 6-foot intervals. Ensure that the tray fittings have a load-carrying capacity that is equal to or greater than that of straight tray sections. Ensure that the radius of tray fittings is based on the minimum bending radius of the cables, as specified by the cable manufacturer.

2.4 MATERIALS

Provide hot-dipped galvanized steel trays with a finish in accordance with ASTM A123/A123M.

PART 3 EXECUTION

Comply with NEMA VE 2 for cable tray installation.

3.1 INSTALLATION

3.1.1 Manufacturer's Instructions

Submit the manufacturer's instructions for cable trays, including special provisions required to install equipment components and system packages. Ensure that the instructions specify impedances, hazards and safety precautions.

3.1.2 Installation Drawings

No later than 30 calendar days before shipment, submit installation drawings to the Contracting Officer for approval. Coordinate drawings with those being used for all other work in the immediate area to ensure that this other work does not conflict with the installation. Include the layout of the cable tray work and details on both horizontal and vertical supports as specified in the paragraph SUPPORTS.

3.1.3 Grounding

Provide properly grounded cable trays by means that has a low-resistance conductor of sufficient capacity, and that is no smaller than No. 1/0 AWG copper. Bond the grounding conductor to cable tray sections and fittings by compatible bolted connections. Consider cable tray sections in tandem assembly as having electrical continuity when these sections are bonded with appropriate high-strength bolts. Provide permanent and continuous effective grounding with an impedance that is low enough to limit the potential above ground and to facilitate operation of overcurrent devices in the circuit. Provide grounding and bonding for cable trays in accordance with NFPA 70.

-- End of Section --

SECTION 27 10 00

BUILDING TELECOMMUNICATIONS CABLING SYSTEM
08/11

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ELECTRONIC COMPONENTS INDUSTRY ASSOCIATION (ECIA)

ECIA EIA/ECA 310-E (2005) Cabinets, Racks, Panels, and Associated Equipment

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 100 (2000; Archived) The Authoritative Dictionary of IEEE Standards Terms

INSULATED CABLE ENGINEERS ASSOCIATION (ICEA)

ICEA S-90-661 (2012) Category 3, 5, & 5e Individually Unshielded Twisted Pair Indoor Cables for Use in General Purpose and LAN Communications Wiring Systems Technical Requirements

NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION (NECA)

NECA/BICSI 568 (2006) Standard for Installing Building Telecommunications Cabling

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI/NEMA WC 66 (2013) Performance Standard for Category 6 and Category 7 100 Ohm Shielded and Unshielded Twisted Pairs

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-455-21 (1988a; R 2012) FOTP-21 - Mating Durability of Fiber Optic Interconnecting Devices

TIA-526-7 (2015a) OFSTP-7 Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant

TIA-568-C.0 (2009; Add 1 2010; Add 2 2012) Generic

Telecommunications Cabling for Customer
Premises

- TIA-568-C.1 (2009; Add 2 2011; Add 1 2012) Commercial Building Telecommunications Cabling Standard
- TIA-568-C.2 (2009; Errata 2010; Add 2 2014; Add 1 2016) Balanced Twisted-Pair Telecommunications Cabling and Components Standards
- TIA-568-C.3 (2008; Add 1 2011) Optical Fiber Cabling Components Standard
- TIA-569 (2019e; Add 1 2022) Telecommunications Pathways and Spaces
- TIA-606 (2021d) Administration Standard for Telecommunications Infrastructure
- TIA-607 (2019d) Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises
- TIA-1152 (2009) Requirements for Field Test Instruments and Measurements for Balanced Twisted-Pair Cabling
- TIA/EIA-604-10 (2002a) FOCIS 10 Fiber Optic Connector Intermateability Standard - Type LC

U.S. FEDERAL COMMUNICATIONS COMMISSION (FCC)

- FCC Part 68 Connection of Terminal Equipment to the Telephone Network (47 CFR 68)

UNDERWRITERS LABORATORIES (UL)

- UL 50 (2024) UL Standard for Safety Enclosures for Electrical Equipment, Non-Environmental Considerations
- UL 444 (2008; Reprint Apr 2015) Communications Cables
- UL 467 (2022) UL Standard for Safety Grounding and Bonding Equipment
- UL 514C (2014; Reprint Feb 2020) UL Standard for Safety Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers
- UL 723 (2020) UL Standard for Safety Test for Surface Burning Characteristics of Building Materials
- UL 969 (2017; Reprint Mar 2018) UL Standard for Safety Marking and Labeling Systems

UL 1286 (2008; Reprint Jan 2018) UL Standard for Safety Office Furnishings

UL 1863 (2004; Reprint Sep 2016) UL Standard for Safety Communication Circuit Accessories

1.2 RELATED REQUIREMENTS

Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and Section 33 82 00 TELECOMMUNICATIONS, OUTSIDE PLANT (OSP), apply to this section with additions and modifications specified herein.

1.3 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in this specification shall be as defined in TIA-568-C.1, TIA-568-C.2, TIA-568-C.3, TIA-569, TIA-606 and IEEE 100 and herein.

1.3.1 Campus Distributor (CD)

A distributor from which the campus backbone cabling emanates. (International expression for main cross-connect (MC).)

1.3.2 Building Distributor (BD)

A distributor in which the building backbone cables terminate and at which connections to the campus backbone cables may be made. (International expression for intermediate cross-connect (IC).)

1.3.3 Floor Distributor (FD)

A distributor used to connect horizontal cable and cabling subsystems or equipment. (International expression for horizontal cross-connect (HC).)

1.3.4 Telecommunications Room (TR)

An enclosed space for housing telecommunications equipment, cable, terminations, and cross-connects. The room is the recognized cross-connect between the backbone cable and the horizontal cabling.

1.3.5 Entrance Facility (EF) (Telecommunications)

An entrance to the building for both private and public network service cables (including wireless) including the entrance point at the building wall and continuing to the equipment room.

1.3.6 Equipment Room (ER) (Telecommunications)

An environmentally controlled centralized space for telecommunications equipment that serves the occupants of a building. Equipment housed therein is considered distinct from a telecommunications room because of the nature of its complexity.

1.3.7 Open Cable

Cabling that is not run in a raceway as defined by NFPA 70. This refers to cabling that is "open" to the space in which the cable has been installed and is therefore exposed to the environmental conditions

associated with that space.

1.3.8 Open Office

A floor space division provided by furniture, moveable partitions, or other means instead of by building walls.

1.3.9 Pathway

A physical infrastructure utilized for the placement and routing of telecommunications cable.

1.4 SYSTEM DESCRIPTION

The building telecommunications cabling and pathway system shall include permanently installed backbone and horizontal cabling, horizontal and backbone pathways, service entrance facilities, work area pathways, telecommunications outlet assemblies, conduit, raceway, and hardware for splicing, terminating, and interconnecting cabling necessary to transport telephone and data (including LAN) between equipment items in a building. The horizontal system shall be wired in a star topology from the telecommunications work area to the floor distributor or campus distributor at the center or hub of the star. The backbone cabling and pathway system includes intrabuilding and interbuilding interconnecting cabling, pathway, and terminal hardware. The intrabuilding backbone provides connectivity from the floor distributors to the building distributors or to the campus distributor and from the building distributors to the campus distributor as required. The backbone system shall be wired in a star topology with the campus distributor at the center or hub of the star. The interbuilding backbone system provides connectivity between the campus distributors and is specified in Section 33 82 00 TELECOMMUNICATIONS OUTSIDE PLANT (OSP). Provide telecommunications pathway systems referenced herein as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

1.5 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Telecommunications drawings; G

Telecommunications Space Drawings; G

In addition to Section 01 33 00 SUBMITTAL PROCEDURES, provide shop drawings in accordance with paragraph SHOP DRAWINGS.

SD-03 Product Data

Telecommunications cabling (backbone and horizontal); G

Patch panels; G

Telecommunications outlet/connector assemblies; G

Equipment support frame; G
Connector blocks; G Spare Parts; G
Submittals shall include the manufacturer's name, trade name, place of manufacture, and catalog model or number. Include performance and characteristic curves. Submittals shall also include applicable federal, military, industry, and technical society publication references. Should manufacturer's data require supplemental information for clarification, the supplemental information shall be submitted as specified in paragraph REGULATORY REQUIREMENTS and as required in Section 01 33 00 SUBMITTAL PROCEDURES.

SD-06 Test Reports

Telecommunications cabling testing; G

SD-07 Certificates

Telecommunications Contractor Qualifications; G

Key Personnel Qualifications; G

Manufacturer Qualifications; G

Test plan; G

SD-09 Manufacturer's Field Reports

Factory reel tests; G

SD-10 Operation and Maintenance Data

Telecommunications cabling and pathway system Data Package 5; G

SD-11 Closeout Submittals

Record Documentation; G

1.6 QUALITY ASSURANCE

1.6.1 Shop Drawings

In exception to Section 01 33 00 SUBMITTAL PROCEDURES, submitted plan drawings shall be a minimum of 11 by 17 inches in size using a minimum scale of 1/8 inch per foot. Include wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Wiring diagrams shall identify circuit terminals and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Drawings shall indicate adequate clearance for operation, maintenance, and replacement of operating equipment devices. Submittals shall include the nameplate data, size, and capacity. Submittals shall also include applicable federal, military, industry, and technical society publication references.

1.6.1.1 Telecommunications Drawings

Provide registered communications distribution designer (RCDD) approved, drawings in accordance with TIA-606. The identifier for each termination and cable shall appear on the drawings. Drawings shall depict final telecommunications installed wiring system infrastructure in accordance with TIA-606. The drawings should provide details required to prove that the distribution system shall properly support connectivity from the EF telecommunications and ER telecommunications, CD's, BD's, and FD's to the telecommunications work area outlets. Provide a plastic laminated schematic of the as-installed telecommunications cable system showing cabling, CD's, BD's, FD's, and the EF and ER for telecommunications keyed to floor plans by room number. Mount the laminated schematic in the EF telecommunications space as directed by the Contracting Officer. The following drawings shall be provided as a minimum:

- a. T1 - Layout of complete building per floor - Building Area/Serving Zone Boundaries, Backbone Systems, and Horizontal Pathways. Layout of complete building per floor. The drawing indicates location of building areas, serving zones, vertical backbone diagrams, telecommunications rooms, access points, pathways, grounding system, and other systems that need to be viewed from the complete building perspective.
- b. T2 - Serving Zones/Building Area Drawings - Drop Locations and Cable Identification (ID'S). Shows a building area or serving zone. These drawings show drop locations, telecommunications rooms, access points and detail call outs for common equipment rooms and other congested areas.
- c. T4 - Typical Detail Drawings - Faceplate Labeling, Firestopping, Americans with Disabilities Act (ADA), Safety, Department of Transportation (DOT). Detailed drawings of symbols and typicals such as faceplate labeling, faceplate types, faceplate population installation procedures, detail racking, and raceways.

1.6.1.2 Telecommunications Space Drawings

Provide T3 drawings in accordance with TIA-606 that include telecommunications rooms plan views, pathway layout (cable tray, racks, ladder-racks, etc.), mechanical/electrical layout, and cabinet, rack, backboard and wall elevations. Drawings shall show layout of applicable equipment including incoming cable stub or connector blocks, building protector assembly, outgoing cable connector blocks, patch panels and equipment spaces and cabinet/racks. Drawings shall include a complete list of equipment and material, equipment rack details, proposed layout and anchorage of equipment and appurtenances, and equipment relationship to other parts of the work including clearance for maintenance and operation. Drawings may also be an enlargement of a congested area of T1 or T2 drawings.

1.6.2 Telecommunications Qualifications

Work under this section shall be performed by and the equipment shall be provided by the approved telecommunications contractor and key personnel. Qualifications shall be provided for: the telecommunications system contractor, the telecommunications system installer, and the supervisor (if different from the installer). A minimum of 30 days prior to installation, submit documentation of the experience of the

telecommunications contractor and of the key personnel.

1.6.2.1 Telecommunications Contractor

The telecommunications contractor shall be a firm which is regularly and professionally engaged in the business of the applications, installation, and testing of the specified telecommunications systems and equipment. The telecommunications contractor shall demonstrate experience in providing successful telecommunications systems within the past 3 years of similar scope and size. Submit documentation for a minimum of three and a maximum of five successful telecommunication system installations for the telecommunications contractor.

1.6.2.2 Key Personnel

Provide key personnel who are regularly and professionally engaged in the business of the application, installation and testing of the specified telecommunications systems and equipment. There may be one key person or more key persons proposed for this solicitation depending upon how many of the key roles each has successfully provided. Each of the key personnel shall demonstrate experience in providing successful telecommunications systems within the past 3 years.

Supervisors and installers assigned to the installation of this system or any of its components shall be Building Industry Consulting Services International (BICSI) Registered Cabling Installers, Technician Level. Submit documentation of current BICSI certification for each of the key personnel.

In lieu of BICSI certification, supervisors and installers assigned to the installation of this system or any of its components shall have a minimum of 3 years experience in the installation of the specified copper and fiber optic cable and components. They shall have factory or factory approved certification from each equipment manufacturer indicating that they are qualified to install and test the provided products. Submit documentation for a minimum of three and a maximum of five successful telecommunication system installations for each of the key personnel. Documentation for each key person shall include at least two successful system installations provided that are equivalent in system size and in construction complexity to the telecommunications system proposed for this solicitation. Include specific experience in installing and testing telecommunications systems and provide the names and locations of at least two project installations successfully completed using optical fiber and copper telecommunications cabling systems. All of the existing telecommunications system installations offered by the key persons as successful experience shall have been in successful full-time service for at least 18 months prior to the issuance date for this solicitation. Provide the name and role of the key person, the title, location, and completed installation date of the referenced project, the referenced project owner point of contact information including name, organization, title, and telephone number, and generally, the referenced project description including system size and construction complexity.

Indicate that all key persons are currently employed by the telecommunications contractor, or have a commitment to the telecommunications contractor to work on this project. All key persons shall be employed by the telecommunications contractor at the date of issuance of this solicitation, or if not, have a commitment to the telecommunications contractor to work on this project by the date that the

bid was due to the Contracting Officer.

Note that only the key personnel approved by the Contracting Officer in the successful proposal shall do work on this solicitation's telecommunications system. Key personnel shall function in the same roles in this contract, as they functioned in the offered successful experience. Any substitutions for the telecommunications contractor's key personnel requires approval from The Contracting Officer.

1.6.2.3 Minimum Manufacturer Qualifications

Cabling, equipment and hardware manufacturers shall have a minimum of 3 years experience in the manufacturing, assembly, and factory testing of components which comply with TIA-568-C.1, TIA-568-C.2 and TIA-568-C.3.

1.6.3 Test Plan

Provide a complete and detailed test plan for the telecommunications cabling system including a complete list of test equipment for the components and accessories for each cable type specified, 60 days prior to the proposed test date. Include procedures for certification, validation, and testing.

1.6.4 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Equipment, materials, installation, and workmanship shall be in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.6.5 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship. Products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year period shall include applications of equipment and materials under similar circumstances and of similar size. The product shall have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period. Where two or more items of the same class of equipment are required, these items shall be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.6.5.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.6.5.2 Material and Equipment Manufacturing Date

Products manufactured more than 1 year prior to date of delivery to site

shall not be used, unless specified otherwise.

1.7 DELIVERY AND STORAGE

Provide protection from weather, moisture, extreme heat and cold, dirt, dust, and other contaminants for telecommunications cabling and equipment placed in storage.

1.8 ENVIRONMENTAL REQUIREMENTS

Connecting hardware shall be rated for operation under ambient conditions of 32 to 140 degrees F and in the range of 0 to 95 percent relative humidity, noncondensing.

1.9 WARRANTY

The equipment items shall be supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

1.10 MAINTENANCE

1.10.1 Operation and Maintenance Manuals

Commercial off the shelf manuals shall be furnished for operation, installation, configuration, and maintenance of products provided as a part of the telecommunications cabling and pathway system, Data Package 5. Submit operations and maintenance data in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA and as specified herein not later than 2 months prior to the date of contract required completion date. In addition to requirements of Data Package 5, include the requirements of paragraphs TELECOMMUNICATIONS DRAWINGS, TELECOMMUNICATIONS SPACE DRAWINGS, and RECORD DOCUMENTATION. Ensure that these drawings and documents depict the as-built configuration.

1.10.2 Record Documentation

Provide T5 drawings including documentation on cables and termination hardware in accordance with TIA-606. T5 drawings shall include schedules to show information for cut-overs and cable plant management, patch panel layouts and cover plate assignments, cross-connect information and connecting terminal layout as a minimum. T5 drawings shall be provided in hard copy format. Provide the following T5 drawing documentation as a minimum:

- a. Cables - A record of installed cable shall be provided in accordance with TIA-606. The cable records shall include only the required data fields in accordance with TIA-606. Include manufacture date of cable with submittal.
- b. Termination Hardware - A record of installed patch panels, cross-connect points, distribution frames, terminating block arrangements and type, and outlets shall be provided in accordance with TIA-606. Documentation shall include the required data fields as a minimum in accordance with TIA-606.

1.10.3 Spare Parts

In addition to the requirements of Section 01 78 23 OPERATION AND MAINTENANCE DATA, provide a complete list of parts and supplies, with current unit prices and source of supply, and a list of spare parts recommended for stocking.

PART 2 PRODUCTS

2.1 COMPONENTS

Components shall be UL or third party certified. Where equipment or materials are specified to conform to industry and technical society reference standards of the organizations, submit proof of such compliance. The label or listing by the specified organization will be acceptable evidence of compliance. In lieu of the label or listing, submit a certificate from an independent testing organization, competent to perform testing, and approved by the Contracting Officer. The certificate shall state that the item has been tested in accordance with the specified organization's test methods and that the item complies with the specified organization's reference standard. Provide a complete system of telecommunications cabling and pathway components using star topology. Provide support structures and pathways, complete with outlets, cables, connecting hardware and telecommunications cabinets/racks. Cabling and interconnecting hardware and components for telecommunications systems shall be UL listed or third party independent testing laboratory certified, and shall comply with NFPA 70 and conform to the requirements specified herein.

2.2 TELECOMMUNICATIONS PATHWAY

Provide telecommunications pathways in accordance with TIA-569 and as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide system furniture pathways in accordance with UL 1286.

2.3 TELECOMMUNICATIONS CABLING

Cabling shall be UL listed for the application and shall comply with TIA-568-C.0, TIA-568-C.1, TIA-568-C.2, TIA-568-C.3 and NFPA 70. Provide a labeling system for cabling as required by TIA-606 and UL 969. Ship cable on reels or in boxes bearing manufacture date for for unshielded twisted pair (UTP) in accordance with ICEA S-90-661 for all cable used on this project. Cabling manufactured more than 12 months prior to date of installation shall not be used.

2.3.1 Horizontal Cabling

Provide horizontal cable in compliance with NFPA 70 and performance characteristics in accordance with TIA-568-C.1.

2.3.1.1 Horizontal Copper

Provide horizontal copper cable, UTP, 100 ohm in accordance with TIA-568-C.2, UL 444, ANSI/NEMA WC 66, ICEA S-90-661 . Provide four each individually twisted pair, minimum size 24 AWG conductors, Category 6, with ablue thermoplastic jacket. Cable shall be imprinted with manufacturers name or identifier, flammability rating, gauge of conductor, transmission performance rating (category designation) and length marking

at regular intervals in accordance with ICEA S-90-661. Provide plenum (CMP), riser (CMR), or general purpose (CM or CMG) communications rated cabling in accordance with NFPA 70. Substitution of a higher rated cable shall be permitted in accordance with NFPA 70. Cables installed in conduit within and under slabs shall be UL listed and labeled for wet locations in accordance with NFPA 70.

2.4 TELECOMMUNICATIONS SPACES

Provide connecting hardware and termination equipment in the telecommunications entrance facility/ telecommunication equipment room to facilitate installation as shown on design drawings for terminating and cross-connecting permanent cabling. Provide telecommunications interconnecting hardware color coding in accordance with TIA-606.

2.4.1 Backboards

Provide void-free, interior grade A-C plywood 3/4 inch thick 4 by 8 feet . Backboards shall be fire rated by manufacturing process. Fire stamp shall be clearly visible. Paint applied over fire retardant backboard shall be UL 723 fire retardant paint. Provide label including paint manufacturer, date painted, UL listing and name of Installer. When painted, paint label and fire stamp shall be clearly visible. Backboards shall be provided on a minimum of two adjacent walls in the telecommunication spaces.

2.4.2 Equipment Support Frame

Provide in accordance with ECIA EIA/ECA 310-E and UL 50.

- b. Racks, floor mounted modular type, 6 gauge steel or 11 gauge aluminum construction, minimum, treated to resist corrosion. Provide rack with vertical and horizontal cable management channels, top and bottom cable troughs, grounding lug and At a minimum, provide two multi-outlet power strips in each rack . One power strip must be 208V, 1-phase; the other must be 120V 1-phase. To minimize accidental shut-off, equip power strips with indicator lights, but no integral on/off switch. Coordinate with owner for outlet configuration. Rack shall be compatible with 19 inches panel mounting.

2.4.3 Connector Blocks

Provide insulation displacement connector (IDC) Type 110 for Category 6 systems. Provide blocks for the number of horizontal and backbone cables terminated on the block plus 25 percent spare.

2.4.4 Patch Panels

Provide ports for the number of horizontal and backbone cables terminated on the panel plus 25 percent spare. Provide pre-connectorized optical fiber and patch cords for patch panels. Provide patch cords, as complete assemblies, with matching connectors as specified. Provide fiber optic patch cables with crossover orientation in accordance with TIA-568-C.3. Patch cords shall meet minimum performance requirements specified in TIA-568-C.1, TIA-568-C.2 and TIA-568-C.3 for cables, cable length and hardware specified.

2.4.4.1 Modular to 110 Block Patch Panel

Provide in accordance with TIA-568-C.1 and TIA-568-C.2. Panels shall be third party verified and shall comply with EIA/TIACategory 6 requirements. Panel shall be constructed of 0.09 inches minimum aluminum and shall be rack mounted and compatible with anECIA EIA/ECA 310-E 19 inches equipment rack. Panel shall provide 48 non-keyed, 8-pin modular ports, wired to T568A. Patch panels shall terminate the building cabling on Type 110 IDCs and shall utilize a printed circuit board interface. The rear of each panel shall have incoming cable strain-relief and routing guides. Panels shall have each port factory numbered and be equipped with laminated plastic nameplates above each port.

2.4.4.2 Fiber Optic Patch Panel

Provide panel for maintenance and cross-connecting of optical fiber cables. Panel shall be constructed of 16 gauge steel or 11 gauge aluminum minimum and shall be rack mounted and compatible with a ECIA EIA/ECA 310-E 19 inches equipment rack. Each panel shall provide 12 single-mode adapters as duplex LC in accordance with TIA/EIA-604-10 with zirconia ceramic alignment sleeves, Provide dust cover for unused adapters. The rear of each panel shall have a cable management tray a minimum of 8 inches deep with removable cover, incoming cable strain-relief and routing guides. Panels shall have each adapter factory numbered and be equipped with laminated plastic nameplates above each adapter.

2.5 TELECOMMUNICATIONS OUTLET/CONNECTOR ASSEMBLIES

2.5.1 Outlet/Connector Copper

Outlet/connectors shall comply with FCC Part 68, TIA-568-C.1, and TIA-568-C.2. UTP outlet/connectors shall be UL 1863 listed, non-keyed, 8-pin modular, constructed of high impact rated thermoplastic housing and shall be third party verified and shall comply with TIA-568-C.2 Category 6 requirements. Outlet/connectors provided for UTP cabling shall meet or exceed the requirements for the cable provided. Outlet/connectors shall be terminated using a Type 110 IDC PC board connector, color-coded for both T568A and T568B wiring. Each outlet/connector shall be wired T568A. UTP outlet/connectors shall comply with TIA-568-C.2 for 200 mating cycles.

2.5.2 Optical Fiber Adapters(Couplers)

Provide optical fiber adapters suitable for duplex LC in accordance with TIA/EIA-604-10 with zirconia ceramic alignment sleeves, as indicated. Provide dust cover for adapters. Optical fiber adapters shall comply with TIA-455-21 for 500mating cycles.

2.5.3 Optical Fiber Connectors

Provide in accordance with TIA-455-21. Optical fiber connectors shall be duplex LC in accordance with TIA/EIA-604-10 with zirconia ceramic alignment sleeves, 8/125 single-mode fiber. The connectors shall provide a maximum attenuation of 0.3 dB at 1310 and 1550 nm with less than a 0.2 dB change after 500 mating cycles.

2.5.4 Cover Plates

Telecommunications cover plates shall comply with UL 514C, and TIA-568-C.1, TIA-568-C.2; flush into match color of receptacle/switch cover plates

specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide labeling in accordance with the paragraph LABELING in this section.

2.6 GROUNDING AND BONDING PRODUCTS

Provide in accordance with UL 467, TIA-607, and NFPA 70. Components shall be identified as required by TIA-606. Provide ground rods, bonding conductors, and grounding busbars as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.7 MANUFACTURER'S NAMEPLATE

Each item of equipment shall have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

2.8 TESTS, INSPECTIONS, AND VERIFICATIONS

2.8.1 Factory Reel Tests

Provide documentation of the testing and verification actions taken by manufacturer to confirm compliance with TIA-568-C.1, TIA-568-C.2, TIA-568-C.3, TIA-526-7 for single mode optical fiber cables.

PART 3 EXECUTION

3.1 INSTALLATION

Install telecommunications cabling and pathway systems, including the horizontal and backbone cable, pathway systems, telecommunications outlet/connector assemblies, and associated hardware in accordance with NECA/BICSI 568, TIA-568-C.1, TIA-568-C.2, TIA-568-C.3, TIA-569, NFPA 70, and UL standards as applicable. Provide cabling in a star topology network. Pathways and outlet boxes shall be installed as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Install telecommunications cabling with copper media in accordance with the following criteria to avoid potential electromagnetic interference between power and telecommunications equipment. The interference ceiling shall not exceed 3.0 volts per meter measured over the usable bandwidth of the telecommunications cabling. Cabling shall be run with horizontal and vertical cable guides in telecommunications spaces with terminating hardware and interconnection equipment.

3.1.1 Cabling

Install UTP telecommunications cabling system as detailed in TIA-568-C.1, TIA-568-C.2, . Screw terminals shall not be used except where specifically indicated on plans. Use an approved insulation displacement connection (IDC) tool kit for copper cable terminations. Do not exceed manufacturers' cable pull tensions for copper and optical fiber cables. Provide a device to monitor cable pull tensions. Do not exceed 25 pounds pull tension for four pair copper cables. Do not chafe or damage outer jacket materials. Use only lubricants approved by cable manufacturer. Do not over cinch cables, or crush cables with staples. For UTP cable, bend radii shall not be less than four times the cable diameter. Cables shall be terminated; no cable shall contain unterminated elements. Cables shall not be spliced. Label cabling in accordance with paragraph LABELING in this section.

3.1.1.1 Horizontal Cabling

Install horizontal cabling as indicated on drawings. Do not untwist Category 6 UTP cables more than one half inch from the point of termination to maintain cable geometry. Provide slack cable in the form of a figure eight (not a service loop) on each end of the cable, 10 feet in the telecommunications room, and 12 inches in the work area outlet..

3.1.2 Pathway Installations

Provide in accordance with TIA-569 and NFPA 70. Provide building pathway as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

3.1.3 Service Entrance Conduit, Underground

Provide service entrance underground as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

3.1.4 Cable Tray Installation

Install cable tray as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Only CMP type cable shall be installed in a plenum.

3.1.5 Work Area Outlets

3.1.5.1 Terminations

Terminate UTP cable in accordance with TIA-568-C.1, TIA-568-C.2 and wiring configuration as specified. Terminate fiber optic cables in accordance with TIA-568-C.3

3.1.5.2 Cover Plates

As a minimum, each outlet/connector shall be labeled as to its function and a unique number to identify cable link in accordance with the paragraph LABELING in this section.

3.1.5.3 Cables

Unshielded twisted pair and fiber optic cables shall have a minimum of 12 inches of slack cable loosely coiled into the telecommunications outlet boxes. Minimum manufacturer's bend radius for each type of cable shall not be exceeded.

3.1.5.4 Pull Cords

Pull cords shall be installed in conduit serving telecommunications outlets that do not have cable installed.

3.1.6 Telecommunications Space Termination

Install termination hardware required for Category 6 system. An insulation displacement tool shall be used for terminating copper cable to insulation displacement connectors.

3.1.6.1 Connector Blocks

Connector blocks shall be rack mounted in orderly rows and columns.

Adequate vertical and horizontal wire routing areas shall be provided between groups of blocks. Install in accordance with industry standard wire routing guides in accordance with TIA-569.

3.1.6.2 Patch Panels

Patch panels shall be mounted racks with sufficient ports to accommodate the installed cable plant plus 25 percent spares.

- a. Copper Patch Panel. Copper cable entering a patch panel shall be secured to the panel as recommended by the manufacturer to prevent movement of the cable.
- b. Fiber Optic Patch Panel. Fiber optic cable loop shall be 3 feet in length. The outer jacket of each cable entering a patch panel shall be secured to the panel to prevent movement of the fibers within the panel, using clamps or brackets specifically manufactured for that purpose.

3.1.6.3 Equipment Support Frames

Install in accordance with TIA-569:

- b. Racks, floor mounted modular type. Permanently anchor rack to the floor in accordance with manufacturer's recommendations.

3.1.7 Grounding and Bonding

Provide in accordance with TIA-607, NFPA 70 and as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

3.2 LABELING

3.2.1 Labels

Provide labeling in accordance with TIA-606. Handwritten labeling is unacceptable. Stenciled lettering for voice and data circuits shall be provided using thermal ink transfer processor laser printer.

3.2.2 Cable

Cables shall be labeled using color labels on both ends with identifiers in accordance with TIA-606.

3.2.3 Termination Hardware

Workstation outlets and patch panel connections shall be labeled using color coded labels with identifiers in accordance with TIA-606.

3.3 FIELD APPLIED PAINTING

Paint electrical equipment as required to match finish of adjacent surfaces or to meet the indicated or specified safety criteria. Painting

shall be as specified in Section 09 90 00 PAINTS AND COATINGS.

3.3.1 Painting Backboards

If backboards are required to be painted, then the manufactured fire retardant backboard must be painted with fire retardant paint, so as not to increase flame spread and smoke density and must be appropriately labeled. Label and fire rating stamp must be unpainted.

3.4 TESTING

3.4.1 Telecommunications Cabling Testing

Perform telecommunications cabling inspection, verification, and performance tests in accordance with TIA-568-C.1. Test equipment shall conform to TIA-1152. Perform optical fiber field inspection tests via attenuation measurements on factory reels and provide results along with manufacturer certification for factory reel tests. Remove failed cable reels from project site upon attenuation test failure.

3.4.1.1 Inspection

Visually inspect UTP and optical fiber jacket materials for UL or third party certification markings. Inspect cabling terminations in telecommunications rooms and at workstations to confirm color code for T568A or T568B pin assignments, and inspect cabling connections to confirm compliance with TIA-568-C.1, TIA-568-C.2. Visually confirm Category 6, marking of outlets, cover plates, outlet/connectors, and patch panels.

3.4.1.2 Verification Tests

UTP backbone copper cabling shall be tested for DC loop resistance, shorts, opens, intermittent faults, and polarity between conductors, and between conductors and shield, if cable has overall shield. Test operation of shorting bars in connection blocks. Test cables after termination but prior to being cross-connected.

For single-mode optical fiber, perform optical fiber end-to-end attenuation tests in accordance with TIA-568-C.3 and TIA-526-7 using Method A, Optical Power Meter and Light Source for single-mode optical fiber. Perform verification acceptance tests.

3.4.1.3 Final Verification Tests

Perform verification tests for UTP systems after the complete telecommunications cabling and workstation outlet/connectors are installed.

- a. Voice Tests. These tests assume that dial tone service has been installed. Connect to the network interface device at the demarcation point. Go off-hook and listen and receive a dial tone. If a test number is available, make and receive a local, long distance, and DSN telephone call.

- b. Data Tests. These tests assume the Information Technology Staff has a network installed and are available to assist with testing. Connect to the network interface device at the demarcation point. Log onto the network to ensure proper connection to the network.

-- End of Section --

SECTION 28 31 76

INTERIOR FIRE ALARM AND MASS NOTIFICATION SYSTEM, ADDRESSABLE
08/20

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ACOUSTICAL SOCIETY OF AMERICA (ASA)

ASA S3.2 (2020) Method for Measuring the Intelligibility of Speech Over Communication Systems (ASA 85)

FM GLOBAL (FM)

FM APP GUIDE (updated on-line) Approval Guide
<http://www.approvalguide.com/>

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C62.41.1 (2002; R 2008) Guide on the Surges Environment in Low-Voltage (1000 V and Less) AC Power Circuits

IEEE C62.41.2 (2002) Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 4 (2021) Standard for Integrated Fire Protection and Life Safety System Testing

NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code

NFPA 72 (2022; ERTA 22-1) National Fire Alarm and Signaling Code

NFPA 90A (2024) Standard for the Installation of Air Conditioning and Ventilating Systems

NFPA 170 (2021) Standard for Fire Safety and Emergency Symbols

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-600-01 (2016; with Change 6, 2021) Fire Protection Engineering for Facilities

UFC 3-601-02 (2021) Operations and Maintenance:

Inspection, Testing, and Maintenance of
Fire Protection Systems

- UFC 4-010-06 (2023) Cybersecurity of Facility-Related Control Systems
- UFC 4-021-01 (2008; with Change 1 and ECB 2018-17) Mass Notification Systems
- UFC 4-211-01 (2017; with Change 3) Aircraft Maintenance Hangars, with Pending Revisions to Change 3

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

- 47 CFR 15 Radio Frequency Devices
- 47 CFR 90 Private Land Mobile Radio Services

UNDERWRITERS LABORATORIES (UL)

- UL 268 (2016; Reprint Nov 2021) UL Standard for Safety Smoke Detectors for Fire Alarm Systems
- UL 268A (2008; Reprint Oct 2014) Smoke Detectors for Duct Application
- UL 464 (2016; Reprint Sep 2017) UL Standard for Safety Audible Signaling Devices for Fire Alarm and Signaling Systems, Including Accessories
- UL 497A (2001; Bul. 2019) UL Standard for Safety Secondary Protectors for Communications Circuits
- UL 497B (2004; Reprint Feb 2022) UL Standard for Safety Protectors for Data Communications and Fire Alarm Circuits
- UL 864 (2014; Reprint May 2020) UL Standard for Safety Control Units and Accessories for Fire Alarm Systems
- UL 1283 (2017) UL Standard for Safety Electromagnetic Interference Filters
- UL 1449 (2021; Reprint Dec 2022) UL Standard for Safety Surge Protective Devices
- UL 1480 (2016; Reprint Sep 2017) UL Standard for Safety Speakers for Fire Alarm and Signaling Systems, Including Accessories
- UL 1638 (2016; Reprint Sep 2017) UL Standard for Safety Visible Signaling Devices for Fire Alarm and Signaling Systems, Including Accessories

UL 1971	(2002; Reprint Oct 2008) Signaling Devices for the Hearing Impaired
UL 2034	(2017; Reprint Apr 2022) UL Standard for Safety Single and Multiple Station Carbon Monoxide Alarms
UL 2075	(2013; Bul. 2019) UL Standard for Safety Gas and Vapor Detectors and Sensors
UL 2572	(2016; Bul. 2018) UL Standard for Safety Mass Notification Systems
UL Fire Prot Dir	(2012) Fire Protection Equipment Directory

1.2 RELATED SECTIONS

Section 25 05 11.04 Cybersecurity for Facility-Related Control Systems - Fire, applies to this section, with the additions and modifications specified herein. In addition, refer to the following sections for related work and coordination:

Section 21 13 13 WET PIPE SPRINKLER SYSTEM, FIRE PROTECTION
Section 21 13 18 PREACTION FIRE SPRINKLER SYSTEMS
Section 07 84 00 FIRESTOPPING for work related to firestopping.

1.3 SUMMARY

1.3.1 Scope

- a. This work includes designing and providing a new, complete, fire alarm and mass notification (MNS) system as described herein and on the contract drawings. Include system wiring, raceways, pull boxes, terminal cabinets, outlet and mounting boxes, control equipment, initiating devices, notification appliances, supervising station fire alarm transmitters/mass notification transceiver, and other accessories and miscellaneous items required for a complete operational system even though each item is not specifically mentioned or described. Provide systems complete and ready for operation. Design and installation must comply with UFC 3-600-01, UFC 4-211-01, UFC 4-010-06 and AFGM 2019-320-02. Fire alarm/MNS must be Monaco MAAP-X.
- b. Provide equipment, materials, installation, workmanship, inspection, and testing in strict accordance with NFPA 72, except as modified herein. The system layout on the drawings show the intent of coverage and suggested locations. Final quantity, system layout, and coordination are the responsibility of the Contractor.
- c. Each remote fire alarm control unit must be powered from a wiring riser specifically for that use or from a local emergency power panel located on the same floor as the remote fire alarm control unit. Where remote fire control units are provided, equipment for notification appliances may be located in the remote fire alarm control units.
- d. The fire alarm and mass notification system must be independent of the building security, building management, and energy/utility monitoring systems other than for control functions.

1.3.2 Qualified Fire Protection Engineer (QFPE)

Services of the QFPE must include:

- a. Reviewing SD-02, SD-03, and SD-05 submittal packages for completeness and compliance with the provisions of this specification. Construction (shop) drawings and calculations must be prepared by, or prepared under the immediate supervision of, the QFPE. The QFPE must affix their professional engineering seal or review stamp with signature to the shop drawings, calculations, and material data sheets, indicating approval prior to submitting the shop drawings to the DFPE.
- b. Providing a letter documenting that the SD-02, SD-03, and SD-05 submittal package has been reviewed and noting any outstanding comments.
- c. Performing in-progress construction surveillance prior to installation of ceilings (rough-in inspection).
- d. Witnessing pre-Government and final Government functional performance testing and performing a final installation review.
- e. Signing applicable certificates under SD-07.

1.4 DEFINITIONS

Wherever mentioned in this specification or on the drawings, the equipment, devices, and functions must be defined as follows:

1.4.1 Interface Device

An addressable device that interconnects hard wired systems or devices to an analog/addressable system.

1.4.2 Fire Alarm and Mass Notification Control Unit (FACU)

A master control unit having the features of a fire alarm control unit (FACU) and an autonomous control unit (ACU) where these units are interconnected to function as a combined fire alarm/mass notification system.

1.4.3 Remote Fire Alarm and Mass Notification Control Unit

A control unit, physically remote from the fire alarm and mass notification control unit, that receives inputs from automatic and manual fire alarm devices; may supply power to detection devices and interface devices; may provide transfer of power to the notification appliances; may provide transfer of condition to relays or devices connected to the control unit; and reports to and receives signals from the fire alarm and mass notification control unit.

1.4.4 Releasing Service Fire Alarm Control Unit (RSFACU)

A control unit listed for releasing service, electronically remote from the fire alarm and mass notification control unit, that receives inputs from automatic and manual fire alarm device; may supply power to detection devices and interface devices; may provide transfer of power to the

notification appliances; may provide transfer of condition to relays of devices connected to the control unit; and reports to the fire alarm control unit. The control unit has a UL listed or FM Approved releasing service and solenoid. The control unit has central processing, memory, input and output terminals. (Refer Section 21 13 18)

1.4.5 Local Operating Console (LOC)

A unit designed to allow emergency responders and/or building occupants to operate the MNS including delivery of recorded messages and/or live voice announcements, initiate visual, textual visual, and audible appliance operation and other relayed functions.

1.4.6 Terminal Cabinet

A steel cabinet with locking, hinge-mounted door where terminal strips are securely mounted inside the cabinet.

1.4.7 Control Module and Relay Module

Terms utilized to describe emergency control function interface devices as defined by NFPA 72.

1.4.8 Designated Fire Protection Engineer (DFPE)

The DoD fire protection engineer that oversees that Area of Responsibility for that project. This is sometimes referred to as the "cognizant" fire protection engineer. Interpret reference to "authority having jurisdiction" and/or AHJ in referenced standards to mean the Designated Fire Protection Engineer (DFPE). The DFPE may be responsible for review of the contractor submittals having a "G" designation, and for witnessing final inspection and testing.

1.4.9 Qualified Fire Protection Engineer (QFPE)

A QFPE is an individual who is a licensed professional engineer (P.E.), who has passed the fire protection engineering written examination administered by the National Council of Examiners for Engineering and Surveying (NCEES) and has relevant fire protection engineering experience with at least three similar projects.

1.5 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval.

Shop drawings (SD-02), product data (SD-03) and calculations (SD-05) must be prepared by the fire alarm designer and combined and submitted as one complete package. Separate SD-03 Product Data into a separate submittal, submitted concurrently. The QFPE must review the SD-02/SD-03/SD-05 submittal package for completeness and compliance with the Contract provisions prior to submission to the Government. The QFPE must provide a Letter of Confirmation that they have reviewed the submittal package for compliance with the contract provisions. This letter must include their registered professional engineer stamp and signature. Partial submittals and submittals not reviewed by the QFPE will be returned by the Government disapproved without review.

Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Qualified Fire Protection Engineer (QFPE); G

Fire alarm system designer; G

Supervisor; G

Technician; G

Installer; G

Test Technician; G

Fire Alarm System Site-Specific Software Acknowledgement; G

SD-02 Shop Drawings

Nameplates; G

Instructions; G

Wiring Diagrams; G

System Layout; G

Notification Appliances; G

Initiating devices; G

Amplifiers; G

Battery Power; G

Voltage Drop Calculations; G

SD-03 Product Data

Fire Alarm and Mass Notification Control Unit (FACU); G

Local Operating Console (LOC); G

Amplifiers; G

Tone Generators; G

Digitalized voice generators; G

Remote Annunciator; G

Manual Stations; G

Smoke Detectors; G

Duct Smoke Detectors; G

Carbon monoxide detector; G
Addressable Interface Devices; G
Addressable Control Modules; G
Isolation Modules; G
Notification Appliances; G
Textual Display Sign Control Panel; G
Textual Display Signs; G
Batteries; G
Battery Chargers; G
Auxiliary Power Supply Panels; G
Surge Protective Devices; G
Alarm Wiring; G
Back Boxes and Conduit; G
Ceiling Bridges for Ceiling-Mounted Appliances; G
Terminal Cabinets; G

Automatic Fire Alarm Transmitters (including housing); G
Mass Notification Transceiver; G
Environmental Enclosures or Guards; G
Document Storage Cabinet; G
Radio Transmitter And Interface Panels; G
Flame Detectors; G
SD-05 Design Data
SD-06 Test Reports
 Test Procedures; G
SD-07 Certificates
 Verification of Compliant Installation; G
 Request for Government Final Test; G
SD-10 Operation and Maintenance Data

Operation and Maintenance (O&M) Instructions; G

Posted Operation and Maintenance (O&M) Instructions; G

Instruction of Government Employees; G

SD-11 Closeout Submittals

As-Built Drawings

Spare Parts

1.6 SYSTEM OPERATION

Fire alarm system/mass notification system including textual display sign control panel(s), components requiring power, except for the FACU(s) power supply, must operate on 24 volts DC unless noted otherwise in this section.

The interior fire alarm and mass notification system must be a complete, supervised, noncoded, analog/addressable fire alarm and mass notification system conforming to NFPA 72, UL 864, and UL 2572. Systems meeting UL 2017 only are not acceptable. The system must be activated into the alarm mode by actuation of an alarm initiating device. The system must remain in the alarm mode until the initiating device is reset and the control unit is reset and restored to normal. The system may be placed in the alarm mode by local microphones, LOC, FACU, or remotely from authorized locations/users.

1.6.1 Alarm Initiating Devices and Notification Appliances (Visual, Voice, Textual)

- a. Connect alarm initiating devices to initiating device circuits (IDC) Class "B", or to signaling line circuits (SLC) Class "B" and installed in accordance with NFPA 72.
- b. Connect notification appliances to notification appliance circuits (NAC) Class "B".

1.6.2 Functions and Operating Features

The system must provide the following functions and operating features:

- a. Power, annunciation, supervision, and control for the system. Addressable systems must be microcomputer (microprocessor or microcontroller) based with a minimum word size of eight bits with sufficient memory to perform as specified.
- b. Visual alarm notification appliances must be synchronized as required by NFPA 72.
- c. Electrical supervision of the primary power (AC) supply, presence of the battery, battery voltage, and placement of system modules within the control unit.
- d. An audible and visual trouble signal to activate upon a single break or open condition, or ground fault. The trouble signal must also operate upon loss of primary power (AC) supply, absence of a battery supply, low battery voltage, or removal of alarm or supervisory

- control unit modules. After the system returns to normal operating conditions, the trouble signal must again sound until the trouble is acknowledged. A smoke detector in the process of being verified for the actual presence of smoke must not initiate a trouble condition.
- e. A trouble signal silence feature that must silence the audible trouble signal, without affecting the visual indicator.
 - f. Program capability via switches in a locked portion of the FACU to bypass the automatic notification appliance circuits, fire reporting system, air handler shutdown and door release features. Operation of this programmed action must indicate on the FACU display as a supervisory or trouble condition.
 - g. Alarm functions must override trouble or supervisory functions. Supervisory functions must override trouble functions.
 - h. The system must be capable of being programmed from the control unit keyboard. Programmed information must be stored in non-volatile memory.
 - i. The system must be capable of operating, supervising, and/or monitoring non-addressable alarm and supervisory devices.
 - j. There must be no limit, other than maximum system capacity, as to the number of addressable devices that may be in alarm simultaneously.
 - k. Where the fire alarm/mass notification system is responsible for initiating an action in another emergency control device or system, the addressable fire alarm relay must be located in the vicinity of the emergency control device.
 - l. An alarm signal must automatically initiate the following functions:
 - (1) Transmission of an alarm signal to the fire department.
 - (2) Visual indication of the device operated on the FACU,
 - (3) Actuation of alarm notification appliances.
 - (4) Recording of the event electronically in the history log of the FA CU.
 - (5) As shown on the system matrix.
 - m. A supervisory signal must automatically initiate the following functions:
 - (1) Visual indication of the device operated on the FACU,
 - (2) As shown on the system matrix.
 - (3) Transmission of a supervisory signal to the fire department.
 - (4) Operation of a duct smoke detector must shut down the appropriate air handler in accordance with NFPA 90A in addition to other requirements of this paragraph and as allowed by NFPA 72.
 - (5) Recording of the event electronically in the history log of the FA CU.

- n. A trouble condition must automatically initiate the following functions:
 - (1) Visual indication of the device operated on the FACU,
 - (2) Transmission of a trouble signal to the fire department.
 - (3) Recording of the event electronically in the history log of the FACU.
- o. Activation of a carbon monoxide alarm initiating device must automatically initiate the following functions:
 - (1) Visual indication of the device operated on the FACU.
 - (2) Transmission of a carbon monoxide alarm signal to the fire department.
 - (3) Activation of all strobes and the audible carbon monoxide message throughout the building.
 - (4) Recording of the event electronically in the history log of the FACU.
- p. System control equipment must be programmed to provide a 60-minute to 180-minute delay in transmission of trouble signals resulting from primary power failure.
- q. Activation of a LOC pushbutton must activate the audible and visual alarms in the facility. The audible message must be the one associated with the pushbutton activated.

1.7 TECHNICAL DATA AND SITE-SPECIFIC SOFTWARE

Technical data and site-specific software (meaning technical data that relates to computer software) that are specifically identified in this project, and may be required in other specifications, must be delivered, strictly in accordance with the CONTRACT CLAUSES. The fire alarm system manufacturer must submit written confirmation of this contract provision as "Fire Alarm System Site-Specific Software Acknowledgement". Identify data delivered by reference to the specification paragraph against which it is furnished. Data to be submitted must include complete system, equipment, and software descriptions. Descriptions must show how the equipment will operate as a system to meet the performance requirements of this contract. The site-specific software data package must also include the following:

- a. Items identified in NFPA 72, titled "Site-Specific Software".
- b. Identification of programmable portions of the system equipment and capabilities.
- c. Description of system revision and expansion capabilities and methods of implementation detailing both equipment and software requirements.
- d. Provision of operational software data on all modes of programmable portions for fire alarm and mass notification.

- e. Description of Fire Alarm and Mass Notification Control Unit equipment operation.
- f. Description of auxiliary and remote equipment operations.
- g. Library of application software.
- h. Operation and maintenance manuals.

1.8 QUALITY ASSURANCE

1.8.1 Submittal Documents

1.8.1.1 Preconstruction Submittals

Within 36 days of contract award but not less than 14 days prior to commencing any work on site, the Contractor must submit the Preconstruction Submittals for review and approval. SD-02, SD-03 and SD-05 submittals received prior to the review and approval of the qualifications of the fire alarm subcontractor and QFPE will be returned disapproved without review. All resultant delays must be the sole responsibility of the Contractor.

1.8.1.2 Shop Drawings

Shop drawings must not be smaller than ANSI D. Drawings must comply with the requirements of NFPA 72 and NFPA 170. Minimum scale for floor plans must be 1/8"=1'.

1.8.1.3 Nameplates

Nameplate illustrations and data to obtain approval by the Contracting Officer before installation.

1.8.1.4 Wiring Diagrams

Three copies plus one digital copy of point-to-point wiring diagrams showing the points of connection and terminals used for electrical field connections in the system, including interconnections between the equipment or systems that are supervised or controlled by the system. Diagrams must show connections from field devices to the FACU, initiating circuits, switches, relays and terminals, including pathway diagrams between the control unit and shared communications equipment within the protected premises. Point-to-point wiring diagrams must be job specific and must not indicate connections or circuits not being utilized. Provide complete riser diagrams indicating the wiring sequence of all devices and their connections to the control equipment. Include a color-code schedule for the wiring.

1.8.1.5 System Layout

Three copies plus one digital copy of plan view drawings showing device locations, terminal cabinet locations, junction boxes, other related equipment, conduit routing, conduit sizes, wire counts, conduit fill calculations, wire color-coding, circuit identification in each conduit, and circuit layouts for all floors. Indicate candela rating of each visual notification appliance. Indicate the wattage of each speaker. Clearly identify the locations of isolation modules. Indicate the addresses of all devices, modules, relays, and similar. Show/identify all

acoustically similar spaces. Indicate if the environment for the FACU is within its environmental listing (e.g. temperature/humidity).

Provide a complete description of the system operation in matrix format similar to the "Typical Input/Output Matrix" included in the Annex of NFPA 72.

1.8.1.6 Notification Appliances

Calculations and supporting data on each circuit to indicate that there is at least 25 percent spare capacity for notification appliances. Annotate data for each circuit on the drawings.

1.8.1.7 Initiating Devices

Calculations and supporting data on each circuit to indicate that there is at least 25 percent spare capacity for initiating devices. Annotate data for each circuit on the drawings.

1.8.1.8 Amplifiers

Calculations and supporting data to indicate that amplifiers have sufficient capacity to simultaneously drive all notification speakers at tapped settings plus 25 percent spare capacity. Annotate data for each circuit on the drawings.

1.8.1.9 Battery Power

Calculations and supporting data as required in paragraph Battery Power Calculations for alarm, alert, and supervisory power requirements. Calculations including ampere-hour requirements for each system component and each control unit component, and the battery recharging period, must be included on the drawings.

1.8.1.10 Voltage Drop Calculations

Voltage drop calculations for each notification circuit indicating that sufficient voltage is available for proper operation of the system and all components, at a minimum rated voltage of the system operating on batteries. Include the calculations on the system layout drawings.

1.8.1.11 Product Data

Three copies plus one digital copy of annotated descriptive data to show the specific model, type, and size of each item. Catalog cuts must also indicate the NRTL listing. The data must be highlighted to show model, size, and options that are intended for consideration. Data must be adequate to demonstrate compliance with all contract requirements. Product data for all equipment must be combined into a single submittal.

Provide an equipment list identifying the type, quantity, make, and model number of each piece of equipment to be provided under this submittal. The equipment list must include the type, quantity, make and model of spare equipment. Types and quantities of equipment submitted must coincide with the types and quantities of equipment used in the battery calculations and those shown on the shop drawings.

1.8.1.12 Operation and Maintenance (O&M) Instructions

Three copies plus one digital copy of the Operation and Maintenance Instructions. The O&M Instructions must be prepared in a single volume or in multiple volumes, with each volume indexed, and may be submitted as a Technical Data Package. Manuals must be approved prior to training. The Interior Fire Alarm And Mass Notification System Operation and Maintenance Instructions must include the following:

- a. "Manufacturer Data Package three as specified in Section 01 78 23 OPERATION AND MAINTENANCE DATA.
- b. Operating manual outlining step-by-step procedures required for system startup, operation, and shutdown. The manual must include the manufacturer's name, model number, service manual, parts list, and preliminary equipment list complete with description of equipment and their basic operating features.
- c. Maintenance manual listing routine maintenance procedures, possible breakdowns and repairs, and troubleshooting guide. The manuals must include conduit layout, equipment layout and simplified wiring, and control diagrams of the system as installed.
- d. Complete procedures for system revision and expansion, detailing both equipment and software requirements.
- e. Software submitted for this project on CD/DVD media utilized.
- f. Printouts of configuration settings for all devices.
- g. Routine maintenance checklist. The routine maintenance checklist must be arranged in a columnar format. The first column must list all installed devices, the second column must state the maintenance activity or state no maintenance required, the third column must state the frequency of the maintenance activity, and the fourth column provided for additional comments or reference. All data (devices, testing frequencies, and similar) must comply with UFC 3-601-02.
- h. A final Equipment List must be submitted with the Operating and Maintenance (O&M) manual.
- i. A copy of the Posted O&M Instructions must be included in each Operating and Maintenance (O&M) manual.

1.8.1.13 As-Built Drawings

The drawings must show the system as installed, including deviations from both the project drawings and the approved shop drawings. These drawings must be submitted within two weeks after the final Government test of the system. At least one set of the as-built (marked-up) drawings must be provided at the time of, or prior to the final Government test.

1.8.2 Qualifications

1.8.2.1 Fire Alarm System Designer

The fire alarm system designer must be certified as a Level IV (minimum) Technician by National Institute for Certification in Engineering Technologies (NICET) in the Fire Alarm Systems subfield of Fire Protection

Engineering Technology or meet the qualifications for a QFPE.

1.8.2.2 Supervisor

A NICET Level III or IV fire alarm technician must supervise the installation of the fire alarm/mass notification system. A fire alarm technician with a minimum of eight years of experience must supervise the installation of the fire alarm/mass notification system. The fire alarm technicians supervising the installation of equipment must be factory trained in the installation, adjustment, testing, and operation of the equipment specified herein and on the drawings.

1.8.2.3 Technician

Fire alarm technicians with a minimum of four years of experience must be utilized to install and terminate fire alarm/mass notification devices, cabinets and control units. The fire alarm technicians installing the equipment must be factory trained in the installation, adjustment, testing, and operation of the equipment specified herein and on the drawings.

1.8.2.4 Installer

A licensed electrician must be allowed to install wire, cable, conduit and backboxes for the fire alarm system/mass notification system. The fire alarm installer must be factory trained in the installation, adjustment, testing, and operation of the equipment specified herein and on the drawings.

1.8.2.5 Test Technician

Fire alarm technicians with a minimum of eight years of experience and NICET Level III or IV utilized in testing and certification of the installation of the fire alarm/mass notification devices, cabinets and control units. The fire alarm technicians testing the equipment must be factory trained in the installation, adjustment, testing, and operation of the equipment installed as part of this project.

1.8.2.6 Manufacturer

Components must be of current design and must be in regular and recurrent production at the time of installation. Provide design, materials, and devices for a protected premises fire alarm system, complete, conforming to NFPA 72, except as specified herein.

1.8.3 Regulatory Requirements

Equipment and material must be listed or approved. Listed or approved, as used in this Section, means listed, labeled or approved by a Nationally Recognized Testing Laboratory (NRTL) such as UL Fire Prot Dir or FM APP GUIDE. The omission of these terms under the description of any item of equipment described must not be construed as waiving this requirement. All listings or approvals by testing laboratories must be from an existing ANSI or UL published standard. The recommended practices stated in the manufacturer's literature or documentation must be considered as mandatory requirements.

1.9 DELIVERY, STORAGE, AND HANDLING

Protect equipment delivered and placed in storage from the weather, humidity, and temperature variation, dirt and dust, and other contaminants.

1.10 MAINTENANCE

1.10.1 Spare Parts

Furnish the following spare parts in the manufacturers original unopened containers:

- a. Five complete sets of system keys.
- b. Two of each type of fuse required by the system.
- c. One manual stations.
- d. Two of each type of detector installed.
- e. Two of each type of detector base and head installed.
- f. One smoke detector manufacturer's test screen, card or magnet for each ten beam smoke detectors, or fraction thereof, installed in the system.
- g. Two of each type of audible and visual alarm device installed.
- h. One textual visual notification appliance.
- i. Two of each type of addressable monitor module installed.
- j. Two of each type of addressable control module installed.
- k. Two 24 V and two 120 VAC surge protective device.

1.10.2 Special Tools

Software, connecting cables and proprietary equipment, necessary for the maintenance, testing, and reprogramming of the equipment must be furnished to the Contracting Officer, prior to the instruction of Government employees. If a laptop is required to program the FACU, a laptop with all software required to modify the program, identical to the one used by the installer, must be provided.

PART 2 PRODUCTS

2.1 GENERAL PRODUCT REQUIREMENT

All fire alarm and mass notification equipment must be new and listed for use under the applicable reference standards. Interfacing of UL 864 or similar approved industry listing with Mass Notification equipment listed to UL 2572 must be done in a laboratory listed configuration, if the software programming features cannot provide a listed interface control.

2.2 MATERIALS AND EQUIPMENT

2.2.1 Standard Products

Provide new materials, equipment, and devices that have been tested by a

nationally recognized testing laboratory and listed for fire protection service when so required by NFPA 72 or this specification. Select material from one manufacturer, where possible, and not a combination of manufacturers, for any particular classification of materials. Material and equipment must be the standard products of a manufacturer regularly engaged in the manufacture of the products for at least 5 years prior to bid opening.

2.2.2 Nameplates

Major components of equipment must have the manufacturer's name, address, type or style, model or serial number, catalog number, date of installation, installing Contractor's name and address, and the contract number provided on a new name plate permanently affixed to the item or equipment. Major components include, but are not limited to, the following:

a. FACU

Nameplates must be etched metal or plastic, permanently attached by screws to control units or adjacent walls.

2.2.3 Keys

Keys and locks for equipment, control units and devices must be identical. Master all keys and locks to a single key as required by the Installation Fire Department.

2.2.4 Instructions

Provide a typeset printed or typewritten instruction card mounted behind a Lexan plastic or glass cover in a stainless steel or aluminum frame. Install the frame in a conspicuous location observable from the FACU. The card must show those steps to be taken by an operator when a signal is received as well as the functional operation of the system under all conditions, normal, alarm, supervisory, and trouble. The instructions must also include procedures for operating live voice microphones. The instructions and their mounting location must be approved by the Contracting Officer before being posted.

2.3 FIRE ALARM AND MASS NOTIFICATION CONTROL UNIT

Provide a complete fire alarm and mass notification control unit (FACU) fully enclosed in a lockable steel cabinet as specified herein. Fire alarm and Mass Notification Control Unit shall be a Monaco MAAP-X control panel. Operations required for testing or for normal care, maintenance, and use of the system must be performed from the front of the enclosure. If more than a single unit is required at a location to form a complete control unit, the unit cabinets must match exactly. The system must be capable of defining any module as an alarm module and report alarm trouble, loss of polling, or as a supervisory module, and reporting supervisory short, supervisory open or loss of polling such as waterflow switches, valve supervisory switches, independent smoke detection systems, relays for output function actuation.

- a. Each control unit must provide power, supervision, control, and logic for the entire system, utilizing solid state, modular components, internally mounted and arranged for easy access. Each control unit must be suitable for operation on a 120 volt, 60 hertz, normal

building power supply. Provide each control unit with supervisory functions for power failure, internal component placement, and operation.

- b. Visual indication of alarm, supervisory, or trouble initiation on the FACU must be by liquid crystal display or similar means with a minimum of 80 characters. The mass notification control unit must have the capability of temporarily deactivate the fire alarm audible notification appliances while delivering voice messages.
- c. Provide secure operator console for initiating recorded messages, strobes and displays; and for delivering live voice messages. Provide capacity for at least eight prerecorded messages. Provide the ability to automatically repeat prerecorded messages. Provide a secure microphone for delivering live messages. Provide adequate discrete outputs to temporarily deactivate fire alarm audible notification, initiate/synchronize strobes and initiate textual visual notification appliances. Provide a complete set of self-diagnostics for controller and appliance network. Provide local diagnostic information display and local diagnostic information and system event log file

2.3.1 Cabinet

Install control unit components in cabinets large enough to accommodate all components and also to allow ample gutter space for interconnection of control units as well as field wiring. The cabinet must be a sturdy steel housing, complete with back box, hinged steel door with cylinder lock, and surface mounting provisions. Panels mounted in gypsum board walls shall be recessed mount; those located on concrete walls shall be surface mount.

The enclosures must be identified by an engraved phenolic resin nameplate. Lettering on the nameplate must say "Fire Alarm and Mass Notification Control Unit" and must not be less than 1-inch high. Provide prominent rigid plastic or metal identification plates for lamps, circuits, meters, fuses, and switches.

2.3.2 Silencing Switches

2.3.2.1 Alarm Silencing Switch

Provide an alarm silencing switch at the FACU that must silence the audible and visual notification appliances. Subsequent activation of initiating devices must cause the notification appliances to re-activate.

2.3.2.2 Supervisory/Trouble Silencing Switch

Provide supervisory and trouble silencing switch(es) that must silence the audible trouble and supervisory signal(s), but not extinguish the visual indicator. This switch must be overridden upon activation of a subsequent supervisory or trouble condition. Audible trouble indication must resound automatically every 24 hours after the silencing feature has been operated if the supervisory or trouble condition still exists.

2.3.3 Non-Interfering

Power and supervise each circuit such that a signal from one device does not prevent the receipt of signals from any other device. Initiating devices must be manually reset by switch from the FACU after the initiating device or devices have been restored to normal.

2.3.4 Audible Notification System

The Audible Notification System must comply with the requirements of NFPA 72 for Emergency Voice/Alarm Communications System requirements, except as specified herein. The system must be a one-way, multi-channel voice notification system incorporating user selectability of a minimum eight distinct sounds for tone signaling, and the incorporation of a voice module for delivery of recorded messages. Audible appliances must produce a three-pulse temporal pattern for three cycles followed by a voice message that is repeated until the control unit is reset or silenced. For carbon monoxide detector activation, audible appliances must produce a four-pulse temporal pattern for three cycles followed by a voice message that is repeated until the control unit is reset or silenced. Automatic messages must be broadcast through speakers throughout the building/facility but not in stairs or elevator cabs. A live voice message must override the automatic audible output through use of a microphone input at the control unit or the LOC.

- a. When using the microphone, live messages must be broadcast throughout a selected floor or floors, or all call. The system must be capable of operating all speakers at the same time.
- b. The microprocessor must actively interrogate circuitry, field wiring, and digital coding necessary for the immediate and accurate rebroadcasting of the stored voice data into the appropriate amplifier input. Loss of operating power, supervisory power, or any other malfunction that could render the digitalized voice module inoperative must automatically cause the three-pulse temporal pattern to take over all functions assigned to the failed unit in the event an alarm is activated.

2.3.4.1 Outputs and Operational Modules

All outputs and operational modules must be fully supervised with on-board diagnostics and trouble reporting circuits. Provide form "C" contacts for system alarm and trouble conditions. Provide circuits for operation of auxiliary appliance during trouble conditions. During a Mass Notification event, the control unit must not generate nor cause any trouble alarms to be generated with the Fire Alarm system.

2.3.4.2 Mass Notification

- a. The system must have the capability of utilizing an LOC with redundant controls of the FACU. Notification Appliance Circuits (NAC) must be provided for the activation of strobe appliances. Audio output must be selectable for line level. A hand-held microphone must be provided and, upon activation, must take priority over any tone signal, recorded message or PA microphone operation in progress, while maintaining the strobe NAC circuit activation.
- b. The Mass Notification functions must override the manual or automatic fire alarm notification,. Other fire alarm functions including transmission of a signal(s) to the fire department must remain operational. When a mass notification announcement is disengaged and a fire alarm condition still exists, the audible and visual notification appliances must resume activation for alarm conditions. The fire alarm message must be of lower priority than all other messages (except any "test" messages) and must not override any other messages.

- c. Messages must be recorded professionally utilizing standard industry methods, in a professional female voice. Submit message content for approval. The Contracting Officer's Technical Representative must approve the MNS audible and text messages. Message and tone volumes must both be at the same decibel level on a continuous loop, with a two second pause in between. Messages recorded from the system microphone will not be accepted. Messages shall be preceded by three rounds of a three pulse temporal pattern (T3) per NFPA 72 unless otherwise indicated. Messages shall utilize 1000 Hz tones (as required in 18.4.2.1 of NFPA 72 - unless otherwise indicated), and per the following, subject to approval by the Contracting Officer's Technical Representative:

Include a message for hangar fire alarm, as indicated in UFC 4-211-01.

Include a message for carbon monoxide.

(NOTE: Base specific messages will be used if they exist, otherwise messages below will be used. Contact the Contracting Officer for the eight required messages.)

- (1) Shelter-in place: "May I have your attention, please. Effective immediately, we are operating "secure and lockdown procedures." All personnel should remain calm and stay where you are. Please await further instructions." Text Message: "ANNOUNCEMENT: SHELTER IN PLACE"
- (2) Bomb Threat Warning: "Attention, attention. A bomb threat has been reported for this area. Effective immediately, we are operating, 'secure and lockdown procedures.' All personnel should remain calm and stay where you are. Please await for further instructions." Text Message: "ANNOUNCEMENT: BOMB THREAT IN THE AREA. SHELTER IN PLACE"
- (3) Evacuation Warning: "Attention, Attention. An emergency has been reported in the building. Please evacuate using the nearest exit." Text Message: "EVACUATE: EMERGENCY"
- (4) Severe Weather Warning: "Your attention please. A severe weather warning has been issued for the area. Take appropriate action and tune in to the local radio or televisions stations for the latest updates." Text Message: "ANNOUNCEMENT: SEVERE WEATHER WARNING"
- (5) Hangar Fire Alarm Message: "Attention, attention. A fire emergency has been reported in the hangar bay. Please evacuate the building using the nearest exit. Do not enter the hangar bay" Text Message: "EVACUATE: HANGAR FIRE EMERGENCY. DO NOT EXIT THROUGH THE HANGAR" Utilize High/Low tone.
- (6) Natural Disaster Warning: "Your attention, please. A natural disaster has either occurred or is expected shortly that will impact the area. Take appropriate action and tune in to the local radio or television stations for the latest updates." Text Message: "ANNOUNCEMENT: NATURAL DISASTER WARNING"
- (7) All Clear Message: "The emergency has now ended. Please resume normal operations. Thank you for your cooperation." Text Message: "ANNOUNCEMENT: "RESUME NORMAL OPERATIONS"

Carbon Monoxide Message: "May I have your attention please. May

I have your attention please. Carbon monoxide has been detected in the building. Please walk to the nearest exit and leave the building." (Provide a 2 second pause.) Note: Utilize three rounds of the Carbon monoxide alert tone, 520 Hz, Temporal 4.)
Text Message: "EVACUATE: CARBON MONOXIDE"

Fire Alarm Message: "Attention, attention. A fire emergency has been reported in the building. Please evacuate the building using the nearest exit." Text Message: "EVACUATE: FIRE EMERGENCY."

- d. Auxiliary Input Module must be designed to be an outboard expansion module to either expand the number of optional LOC's, or allow a telephone interface.

2.3.5 Memory

Provide each control unit with non-volatile memory and logic for all functions. The use of long life batteries, capacitors, or other age-dependent devices must not be considered as equal to non-volatile processors, PROMS, or EPROMS.

2.3.6 Field Programmability

Provide control units and control units that are fully field programmable for both input and output of control, initiation, notification, supervisory, and trouble functions. The system program configuration must be menu driven. System changes must be password protected. Any proprietary equipment and proprietary software needed by qualified technicians to implement future changes to the fire alarm system must be provided as part of this contract.

2.3.7 Input/Output Modifications

The FACU must contain features that allow the bypassing of input devices from the system or the modification of system outputs. These control features must consist of a control unit mounted keypad and a keyboard. Any bypass or modification to the system must indicate a trouble condition on the FACU.

2.3.8 Resetting

Provide the necessary controls to prevent the resetting of any alarm, supervisory, or trouble signal while the alarm, supervisory or trouble condition on the system still exists.

2.3.9 Walk Test

The FACU must have a walk test feature. When using this feature, operation of initiating devices must result in limited system outputs, so that the notification appliances operate for only a few seconds and the event is indicated in the history log, but no other outputs occur.

2.3.10 History Logging

The control unit must have the ability to store a minimum of 400 events in a log. These events must be stored in a battery-protected memory and must remain in the memory until the memory is downloaded or cleared manually. Resetting of the control unit must not clear the memory.

2.3.11 Manual Access

An operator at the control unit, having a proper access level, must have the capability to manually access the following information for each initiating device.

- a. Primary status.
- b. Device type.
- c. Present average value.
- d. Present sensitivity selected.
- e. Detector range (normal, dirty).

2.3.12 Heat Detector Self-Test Routines

Automatic self-test routines must be performed on each detector that will functionally check detector sensitivity electronics and ensure the accuracy of the value being transmitted. Any detector that fails this test must indicate a trouble condition with the detector location at the control unit.

2.4 LOCAL OPERATING CONSOLES (LOC)

2.4.1 General

The LOC must consist of a remote microphone station incorporating a push-to-talk (PTT) hand-held mass notification microphone labeled "Mass Notification Microphone" and system status indicators. The LOC must have the capability of being utilized to activate prerecorded messages. The unit must incorporate microphone override of any tone generation or recorded messages. The unit must be fully supervised from the FACU. The housing for the LOC must not be lockable. Hand-held microphones must be housed in a separate protective cabinet. The cabinet must be accessible without the use of a key or other tool. The location of the microphones must be approved by the Designated Fire Protection Engineer (DFPE).

Adjacent to the MNS microphone shall be a nonemergency paging microphone labeled "Non-Emergency Paging Microphone", which does not notify the Base Fire Department when used. Activation of the nonemergency PA microphone must not initiate activation of visual notification appliances or LED text displays. The PA paging function must not override any alarm or notification functions.

2.4.2 Multiple LOCs

When an installation has more than one LOC, the LOCs must be programmed to allow only one LOC to be available for emergency paging or MNS messaging at a time. Once one LOC becomes active, all other LOC's will have an indication that the system is busy (Amber Busy Light) and cannot be used at that time. This is to avoid two messages being given at the same time. It must be possible to override or lockout the LOC's from the FACU.

2.5 AMPLIFIERS, PREAMPLIFIERS, TONE GENERATORS

Any amplifiers, preamplifiers, tone generators, digitalized voice generators, and other hardware necessary for a complete, operational,

textual audible circuit conforming to NFPA 72 must be housed in a remote FACU, terminal cabinet, or in the FACU. Individual amplifiers must be 100 watts maximum.

2.5.1 Operation

The system must automatically operate and control all building speakers.

2.5.2 Construction

Amplifiers must utilize computer grade solid state components and must be provided with output protection devices sufficient to protect the amplifier against any transient up to 10 times the highest rated voltage in the system.

2.5.3 Inputs

Equip each system with separate inputs for the tone generator, digitalized voice driver and control unit mounted microphone. Microphone inputs must be of the low impedance, balanced line type. Both microphone and tone generator input must be operational on any amplifier.

2.5.4 Tone Generator

The tone generator must produce a three-pulse temporal pattern and must be constantly repeated until interrupted by either the digitalized voice message, the microphone input, or the alarm silence mode as specified. The tone generator must be single channel with an automatic backup generator per channel such that failure of the primary tone generator causes the backup generator to automatically take over the functions of the failed unit and also causes transfer of the common trouble relay. The tone generator must be provided with securely attached labels to identify the component as a tone generator and to identify the specific tone it produces.

2.5.5 Protection Circuits

Each amplifier must be constantly supervised for any condition that could render the amplifier inoperable at its maximum output. Failure of any component must cause illumination of a visual "amplifier trouble" indicator on the control unit, appropriate logging of the condition in the history log, and other actions for trouble conditions as specified.

2.6 REMOTE ANNUNCIATOR

Provide a semi-recessed mounted annunciator that includes an LCD display. The display must indicate the device in trouble/alarm or any supervisory device. Display the device name, address. The remote annunciator must duplicate functions of the FACU for message display, fire alarm, supervisory alarm, and trouble conditions, visual and audible notification, and system reset functions. Remote annunciator must require the use of a key for accessing the reset, control and other functions.

A building floor plan must be provided and mounted (behind Plexiglass or similar protective material) at the annunciator location. The floor plan must indicate all rooms by name and number including the locations of stairs and elevators. The floor plan must show all devices and their programmed address to facilitate identification of their physical location from the LCD display information.

2.7 MANUAL STATIONS

Provide metal or plastic, semi-flush mounted, double-action, addressable manual stations, that are not subject to operation by jarring or vibration. Stations must be equipped with screw terminals for each conductor. Stations that require the replacement of any portion of the device after activation are not permitted. Stations must be finished in red with molded raised lettering operating instructions of contrasting color. The use of a key must be required to reset the station. Provide NEMA 4 manual stations in hangar bays and Class I Division 1 and 2 devices where indicated.

2.8 SMOKE DETECTORS

2.8.1 Spot Type Detectors

Provide addressable photoelectric smoke detectors as follows:

- a. Provide analog/addressable photoelectric smoke detectors utilizing the photoelectric light scattering principle for operation in accordance with UL 268. Smoke detectors must be listed for use with the FACU.
- b. Provide self-restoring type detectors that do not require any readjustment after actuation at the FACU to restore them to normal operation. The detector must have a visual indicator to show actuation.
- c. Vibration must have no effect on the detector's operation. Protect the detection chamber with a fine mesh metallic screen that prevents the entrance of insects or airborne materials. The screen must not inhibit the movement of smoke particles into the chamber.
- d. Provide twist lock bases with screw terminals for each conductor. The detectors must maintain contact with their bases without the use of springs.
- e. The detector address must identify the particular unit, its location within the system, and its sensitivity setting. Detectors must be of the low voltage type rated for use on a 24 VDC system.

2.8.2 Duct Smoke Detectors

Duct-mounted addressable photoelectric smoke detectors must consist of a smoke detector, as specified in paragraph Spot Type Detectors, mounted in a special housing fitted with duct sampling tubes. Detector circuitry must be mounted in a metallic or plastic enclosure exterior to the duct. Detectors must be listed for operation over the complete range of air velocities, temperature and humidity expected at the detector when the air-handling system is operating, at a minimum, 100 fpm. Detectors must be powered from the FACU.

- a. Sampling tubes must run the full width of the duct. The duct detector package must conform to the requirements of NFPA 90A, UL 268A, and must be listed for use in air-handling systems. The control functions, operation, reset, and bypass must be controlled from the FACU.
- b. Lights to indicate the operation and alarm condition must be visible

and accessible with the unit installed and the cover in place. Remote indicators and keyed test stations must be provided. Remote indicators as well as the affected fan units must be properly identified in etched plastic placards.

- c. Detectors must provide for control of auxiliary contacts that provide control, interlock, and shutdown functions specified in Section 23 09 00 to INSTRUMENTATION AND CONTROL FOR HVAC. Auxiliary contacts provide for this function must be located within 3 feet of the controlled circuit or appliance. The auxiliary contacts must be supplied by the fire alarm system manufacturer to ensure complete system compatibility.

2.9 FLAME DETECTORS

Detectors must be sensitive to the micron range best suited for their intended use. Detectors must operate over electrically supervised wiring circuits and the loss of power to the detector must result in a trouble signal. A self-test feature must be provided for each detector to be individually tested.

2.9.1 Infrared (IR) Single Frequency Flame Detector

The detector must be sensitive in the range of $_0.15$ to $_0.27$ micrometers only.

2.9.2 Infrared (IR) Multi Frequency Flame Detector

The IR detector must consist of three or more IR sensors, each selected for a different IR frequency. The primary sensor must be sensitive in the range of 0.15 to 0.27 micrometers only. Secondary sensors are tuned to different IR wavelengths to null out the effect of black body radiation to the primary sensor.

2.9.3 Ultraviolet (UV) Flame Detectors

UV flame detector must be of the narrow band response type which operates on radiated ultraviolet energy and must be sensitive in the range of 0.15 to 0.27 micrometers only. The cone of vision must be 80 degrees or greater. Each detector must be completely insensitive to light sources in the visible frequency range.

2.9.4 Combination UV/IR Flame Detector

The UV/IR detector must provide discrimination against false alarms by requiring both UV and IR flame detection before an alarm is sent. The UV sensor must be sensitive in the range of 0.185 to 0.265 micrometers only. The IR sensor must be sensitive in the range of 0.15_____ to 0.27 micrometers only. Detectors must be completely insensitive to light sources in the visible frequency range.

2.10 CARBON MONOXIDE DETECTOR

Analog/addressable carbon monoxide (CO) detectors must be listed to UL 2075 and set to respond to the sensitivity limits of UL 2034. Carbon monoxide detectors must be listed for use with fire alarm control units. Detectors must be surface mounted in the horizontal orientation and supported independently of wiring connections. Detectors must be self-restoring. For FACU with no listed compatible addressable CO detectors, provide

listed 4-wire detectors. Do not provide CO detectors with local alarms. Detector must be provided with an LED status indicator.

- a. Where 4-wire CO detectors are necessary, each 4-wire CO detector must be individually monitored via addressable interface modules for alarm and off normal/trouble conditions (including loss of power to the individual detector). Power circuits for 4-wire CO detectors must be dedicated to powering the CO detectors only. Battery powered and 120 VAC powered detectors are prohibited.
- b. Wiring connections must be made by means of screw terminals and detectors must be equipped with trouble relays. Detectors must be able to mount a single-gang electrical box.
- c. A trouble condition at an individual CO detector must not affect any other CO detectors. CO detectors must be powered by the FACU.
- d. Detectors must be provided with a means to test CO gas entry into the CO sensing cell.

2.11 ADDRESSABLE INTERFACE DEVICES

The initiating device being monitored must be configured as a Class "B" initiating device circuits. The module must be listed as compatible with the control unit. The module must provide address setting means compatible with the control unit's SLC supervision and store an internal identifying code. Monitor module must contain an integral LED that flashes each time the monitor module is polled and is visible through the device cover plate. Pull stations with a monitor module in a common backbox are not required to have an LED. Modules must be listed for the environmental conditions in which they will be installed.

2.12 ADDRESSABLE CONTROL MODULES

The control module must be capable of operating as a relay (dry contact form C) for interfacing the control unit with other systems, and to control door holders or initiate elevator fire service. The module must be listed as compatible with the control unit. The indicating device or the external load being controlled must be configured as Class B notification appliance circuits. The system must be capable of supervising, audible, visual and dry contact circuits. The control module must have both an input and output address. The supervision must detect a short on the supervised circuit and must prevent power from being applied to the circuit. The control model must provide address setting means compatible with the control unit's SLC supervision and store an internal identifying code. The control module must contain an integral LED that flashes each time the control module is polled and is visible through the device cover plate. Control Modules must be listed for the environmental conditions in which they will be installed.

2.13 NOTIFICATION APPLIANCES

2.13.1 Audible Notification Appliances

Audible appliances must conform to the applicable requirements of UL 464. Appliances must be connected into notification appliance circuits. Surface mounted audible appliances must be painted white. Recessed audible appliances must be installed with a grill that is factory painted white.

2.13.1.1 Speakers

- a. Speakers must conform to the applicable requirements of UL 1480. Speakers must have six different sound output levels and operate with audio line input levels of 70.7 VRMs and 25 VRMs, by means of selectable tap settings. Interior speaker tap settings must include taps of 1/4, 1/2, 1, and 2 watt, at a minimum. Exterior speakers must also be multi-tapped with no more than 15 watt maximum setting. Speakers must incorporate a high efficiency speaker for maximum output at minimum power across a frequency range of 400 Hz to 4,000 Hz, and must have a sealed back construction, and must be selected and located to achieve required intelligibility. Speakers must be capable of installation on standard 4-inch square electrical boxes. Where speakers and strobes are provided in the same location, they may be combined into a single unit. All inputs must be polarized for compatibility with standard reverse polarity supervision of circuit wiring via the FACU. Speakers in the hangar bays must be rated for wet locations, NEMA 4, and may be single tapped. Speakers in classified or secure areas must also be rated for the classified or secure area in which they are located.
- b. Provide speaker mounting plates constructed of cold rolled steel having a minimum thickness of 16 gage or molded high impact plastic and equipped with mounting holes and other openings as needed for a complete installation. Fabrication marks and holes must be ground and finished to provide a smooth and neat appearance for each plate. Each plate must be primed and painted.
- c. Speakers must utilize screw terminals for termination of all field wiring.
- d. The hangar bay is a large cavernous area which is typically difficult to meet intelligibility per UFC 4-021-01. It will require carefully selected speakers not typical for office environments. Use of Ease-Evac or a similar program is recommended to model intelligibility in the hangar bay before installation to minimize repeat intelligibility testing, if available for the hangar speaker selected. Appliances in the hangar bays shall be suitable for wet location, NEMA 4 (or equivalent), and hazardous location where indicated.

2.13.2 Visual Notification Appliances

Visual notification appliances must conform to the applicable requirements of UL 1638, UL 1971 and conform to the Architectural Barriers Act (ABA). Visual Notification Appliances must have clear high intensity optic lens, xenon flash tubes, or light emitting diode (LED) and be marked "Alert" in letters of contrasting color. The light pattern must be disbursed so that it is visible above and below the strobe and from a 90 degree angle on both sides of the strobe. Strobe flash rate must be 1 flash per second and a minimum of 15 candela based on the UL 1971 test. Strobe must be surface mounted. Appliances in classified locations must also be rated for the classified area in which they are located.

Visual notification appliances in the hangar bay shall be suitable for wet location, NEMA 4, and shall be 177 candela around the perimeter of the hangar bay (not including the door) per NFPA 72 spacing requirements.

2.13.3 Textual Display Signs

Textual display signs must be LED, 24 V, with a height necessary to meet the requirements of NFPA 72. The text display must spell out the word "EVACUATE" or "ANNOUNCEMENT" and the remainder of the emergency instructions as appropriate. Refer to section 2.3.4.2 for messages. The design of text display must be such that it cannot be read when not illuminated. Textual notification in the hangar bays are not required to be suitable for wet location, NEMA 4 or 3R.

LED text displays must meet the following requirements at a minimum:

- a. Two lines of information for high priority messaging.
- b. Minimum of 20 characters per line (40 total) displayed.
- c. Text must be no less than height requirements and color/contrast requirements of NFPA 72.
- e. Display must be wall or ceiling mounted.
- f. Mounting brackets for a convenient wall/cubicle mount.
- g. During non-emergency periods, display date and time.
- h. The system must interface with the textual display sign control panel to activate the proper message.

2.14 ELECTRIC POWER

2.14.1 Primary Power

Power must be 120 VAC 60 Hz service for the FACU from the AC service to the building in accordance with NFPA 72.

2.15 SECONDARY POWER SUPPLY

Provide for system operation in the event of primary power source failure. Transfer from normal to auxiliary (secondary) power or restoration from auxiliary to normal power must be automatic and must not cause transmission of a false alarm.

2.15.1 Batteries

Provide sealed, maintenance-free, sealed lead acid batteries as the source for emergency power to the FACU. Batteries must contain suspended electrolyte. The battery system must be maintained in a fully charged condition by means of a solid state battery charger. Provide an automatic transfer switch to transfer the load to the batteries in the event of the failure of primary power.

2.15.1.1 Capacity

Battery size must be the greater of the following two capacities. This capacity applies to every control unit associated with this system, including supplemental notification appliance circuit panels, auxiliary power supply panels, fire alarm transmitters, and Base-wide mass notification transceivers. When determining the required capacity under alarm condition, visual notification appliances must include both textual

and non-textual type appliances.

- a. Sufficient capacity to operate the fire alarm system under supervisory and trouble conditions, including audible trouble signal devices for 48 hours and audible and visual signal devices under alarm conditions for an additional 15 minutes.
- b. Sufficient capacity to operate the mass notification for 60 minutes after loss of AC power.

2.15.1.2 Battery Power Calculations

- a. Verify that battery capacity exceeds supervisory and alarm power requirements for the criteria noted in the paragraph "Capacity" above.
 - (1) Substantiate the battery calculations for alarm and supervisory power requirements. Include ampere-hour requirements for each system component and each control unit component, and compliance with UL 864.
 - (2) Provide complete battery calculations for both the alarm and supervisory power requirements. Submit ampere-hour requirements for each system component with the calculations.
 - (3) Provide voltage drop calculations to indicate that sufficient voltage is available for proper operation of the system and all components. Calculations must be performed using the minimum rated voltage of each component.
- b. For battery calculations assume a starting voltage of 24 VDC for starting the calculations to size the batteries. Calculate the required Amp-Hours for the specified standby time, and then calculate the required Amp-Hours for the specified alarm time. Using 20.4 VDC as starting voltage, perform a voltage drop calculation for circuits containing device and/or appliances remote from the power sources.

2.15.2 Battery Chargers

Provide a solid state, fully automatic, variable charging rate battery charger. The charger must be capable of providing 120 percent of the connected system load and must maintain the batteries at full charge. In the event the batteries are fully discharged (20.4 Volts dc), the charger must recharge the batteries back to 95 percent of full charge within 48 hours after a single discharge cycle as described in paragraph CAPACITY above. Provide pilot light to indicate when batteries are manually placed on a high rate of charge as part of the unit assembly if a high rate switch is provided.

2.16 SURGE PROTECTIVE DEVICES

Surge protective devices must be provided to suppress all voltage transients which might damage fire alarm control unit components. Systems having circuits located outdoors, communications equipment must be protected against surges induced on any signaling line circuit. Cables and conductors, that serve as communications links, must have surge protection circuits installed at each end. The surge protective device must wire in series to the power supply of the protected equipment with screw terminations. Line voltage surge arrestor must be installed directly adjacent to the power panel where the FACU breaker is located.

- a. Surge protective devices for nominal 120 VAC must be UL 1449 listed with a maximum 500 volt suppression level and have a maximum response time of 5 nanoseconds. The surge protective device must also meet IEEE C62.41.1 and IEEE C62.41.2 category B tests for surge capacity. The surge protective device must feature multi-stage construction and be provided with a long-life indicator lamp (either light emitting diode or neon) which extinguishes upon failure of protected components. Any unit fusing must be externally accessible.
- b. Surge protective devices for nominal 24 VAC, fire alarm telephone dialer, or ethernet connection must be UL 497B listed, meet IEEE C62.41.1 and have a maximum response time of 1-nanosecond. The surge protective device must feature multi-stage construction and be self-resetting. The surge protective device must be a base and plug style. The base assembly must have screw terminals for fire alarm wiring. The base assembly must accept "plug-in" surge protective module.
- c. All surge protective devices (SPD) must be the standard product of a single manufacturer and be equal or better than the following:
 - (1) For 120 VAC nominal line voltage: UL 1449 and UL 1283 listed, series connected 120 VAC, 20A rated, surge protective device in a NEMA 4 enclosure. Minimum 50,000 amp surge current rating with EMI/RFI filtering and a dry contact circuit for remote monitoring of surge protection status.
 - (2) For 24-volt nominal line voltage: UL 497B listed, series connected low voltage, 24-volt, 5A rated, loop circuit protector, base and replaceable module.
 - (3) For alarm telephone dialers: UL 497A listed, series connected, 130-volt, 150 mA rated with self-resetting fuse, dialer circuit protector with modular plug and play.
 - (4) For IP-DACTS: UL 497B listed, series connected, 6.4-volt, 1.5A rated with 20 kA/pair surge current, data network protector with modular plug and play.

2.17 WIRING

Provide wiring materials under this section as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM with the additions and modifications specified herein.

2.17.1 Alarm Wiring

IDC and SLC wiring must be fiber optic or solid copper cable in accordance with the manufacturers requirements. Copper signaling line circuits must be minimum 18 AWG size. Initiating device circuit and notification device circuit field wiring must be No. 16 AWG size conductors at a minimum. Speaker circuits must be copper No. 16AWG size twisted and shielded conductors at a minimum. Wiring for textual notification appliance circuits must be in accordance with manufacturer's requirements but must be supervised by the FACU. Wire size must be sufficient to prevent voltage drop problems. Circuits operating at 24 VDC must not operate at less than the listed voltages for the detectors and/or appliances. Power wiring, operating at 120 VAC minimum, must be a minimum No. 12 AWG solid

copper having similar insulation. Acceptable power-limited cables are FPL, FPLR or FPLP as appropriate with red colored covering. Nonpower-limited cables must comply with NFPA 70.

All wiring shall be in EMT or rigid conduit, except terminations which may experience movement may be provided with up to 5 feet of flexible conduit. All devices, wiring, junction boxes and conduit in the hangar bays must be installed per NFPA 70 for wet location, NEMA 4. Installation in the hangar bay shall be per NEC for Class I Division 2 locations to 18" above the hangar floor, and Class I Division 1 locations below the hangar floor.

2.18 CONTAINMENT SYSTEM MONITORING PANEL

2.18.1 Containment Monitoring System Interface

The containment system monitoring panel is provided with Dock 80. Interface with Dock 80 FACU to monitor containment system. Refer drawings for additional information.

2.19 AUTOMATIC FIRE ALARM TRANSMITTERS

2.19.1 Radio Transmitter and Interface Panels

Transmitters must be compatible with proprietary supervising station receiving equipment. Each radio alarm transmitter must be the manufacturer's recognized commercial product, completely assembled, wired, factory tested, and delivered ready for installation and operation. Transmitters must be provided in accordance with applicable portions of NFPA 72, Federal Communications Commission (FCC) 47 CFR 90 and Federal Communications Commission (FCC) 47 CFR 15. Transmitter electronics module must be contained within the physical housing as an integral, removable assembly. The proprietary supervising station receiving equipment is a Monaco D21 system and the transmitter must be fully compatible with this equipment. At the contractors option, and if listed, the transmitter may be housed in the same control unit as the FACU. The transmitter must be narrowband radio, with FCC certification for narrowband operation and meets the requirements of the NTIA (National Telecommunications and Information Administration) Manual of Regulations and Procedures for Federal Frequency Management.

2.19.1.1 Operation

Operate each transmitter from 120-volt ac power. In the event of 120-volt ac power loss, the transmitter must automatically switch to battery operation. Switchover must be accomplished with no interruption of protective service, and must automatically transmit a trouble message. Upon restoration of ac power, transfer back to normal ac power supply must also be automatic.

2.19.1.2 Battery Power

Transmitter standby battery capacity must provide sufficient power to operate the transmitter in a normal standby status for a minimum of 72 hours and be capable of transmitting alarms during that period.

2.19.1.3 Transmitter Housing

Use NEMA Type 1 for housing. The housing must contain a lock that is

keyed identical to the fire alarm system for the building. Radio alarm transmitter housing must be factory painted with a suitable priming coat and not less than two coats of a hard, durable weatherproof enamel.

2.19.1.4 Antenna

Antenna must be omnidirectional, coaxial, halfwave dipole antennas for radio alarm transmitters with a driving point impedance to match transmitter output. The antenna and antenna mounts must be corrosion resistant and designed to withstand wind velocities of 100 mph. Do not mount antennas to any portion of the building roofing system. Protect the antenna from physical damage.

2.19.2 Signals to Be Transmitted to the Base Receiving Station

The following signals must be sent to the Monaco D21 base receiving station by point:

- a. Sprinkler waterflow
- b. Manual pull stations
- c. Smoke detectors
- d. Duct smoke detectors
- e. Carbon monoxide detected

Sprinkler valve supervision

Mass Notification System activated

- i. Hangar Fire Alarm

As shown on the system matrix

2.20 SYSTEM MONITORING

2.20.1 Valves

Each valve affecting the proper operation of a fire protection system, including automatic sprinkler control valves, sprinkler service entrance valve, isolating valves for area sprinklers, and waterflow or supervisory switches, must be electrically monitored to ensure its proper position. Provide each tamper switch with a separate address.

2.20.2 High/Low Nitrogen Supervisory Switches

Provide monitoring of high and low supervisory nitrogen for preaction systems. Each air supervisory switch must have a separate address. The device must contain double pole, double throw contacts. Operation of the switch must cause a supervisory signal to be transmitted to the FACU when nitrogen pressure in the system monitored sprinkler system increases more than 5 psi above the normal system pressure or drops halfway from the normal pressure to the tripping point.

2.20.3 Room Low Temperature Supervisory Switch

Provide monitoring of the listed supervisory air temperature switch for the fire protection room. Switch must cause a supervisory signal to be transmitted to the FACU whenever the temperature in the room drops to below 32 degrees F. Device must reset when temperature rises above 32 degrees F.

2.21 ENVIRONMENTAL ENCLOSURES OR GUARDS

Environmental enclosures may be provided to permit fire alarm/mass notification components to be used in areas that exceed the environmental limits of the listing, except for manual releasing stations. The enclosure must be listed for the device or appliance as either a manufactured part number or as a listed compatible accessory for the component is currently listed. Guards required to deter mechanical damage must be either a listed manufactured part or a listed accessory for the category of the initiating device or notification appliance.

PART 3 EXECUTION

3.1 VERIFYING ACTUAL FIELD CONDITIONS

Before commencing work, examine all adjoining work on which the contractor's work is in any way dependent for perfect workmanship according to the intent of this specification section, and report to the Contracting Officer's Representative any condition which prevents performance of first class work. No "waiver of responsibility" for incomplete, inadequate or defective adjoining work will be considered unless notice has been filed before submittal of a proposal.

3.2 INSTALLATION

3.2.1 Fire Alarm and Mass Notification Control Unit (FACU)

Locate the FACU where indicated on the drawings. Surface mount the enclosure with the top of the cabinet 6 feet above the finished floor or center the cabinet at 5 feet, whichever is lower. Conductor terminations must be labeled and a drawing containing conductors, their labels, their circuits, and their interconnection must be permanently mounted in the FACU. Locate the document storage cabinet adjacent to the FACU unless the Contracting Officer directs otherwise.

3.2.2 Battery Cabinets

When batteries will not fit in the FACU, locate battery cabinets below or adjacent to the FACU. Battery cabinets must be installed at an accessible location when standing at floor level. Battery cabinets must not be installed lower than 12 inches above finished floor, measured to the bottom of the cabinet, nor higher than 36 inches above the floor, measured to the top of the cabinet. Battery cabinets must not be greater than 8" deep. Installing batteries above drop ceilings or in inaccessible locations is prohibited. Battery cabinets must be large enough to accommodate batteries and also to allow ample gutter space for interconnection of control units as well as field wiring. The cabinet must be provided in a sturdy steel housing, complete with back box, hinged steel door with cylinder lock, and surface mounting provisions. The cabinet must be identified by an engraved phenolic resin nameplate. Lettering on the nameplate must indicate the control unit(s) the batteries power and must not be less than 1-inch high.

3.2.3 Manual Stations

Locate manual stations as required by NFPA 72. Mount stations so they are located no farther than 5 feet from the exit door they serve, measured horizontally. Manual stations must be mounted at 44 inches measured to the operating handle. Provide engraved plastic or metallic alphanumeric identification, keyed to the Posted O&M Instructions.

3.2.4 Notification Appliances

- a. Locate notification appliance devices as required by NFPA 72 and to meet the intelligibility requirements. Where more than two visual notification appliances are located in the same room or corridor or field of view, provide synchronized operation. Devices must use screw terminals for all field wiring. Audible and visual notification appliances mounted in acoustical ceiling tiles must be centered in the tiles plus or minus 2 inches. Provide engraved plastic or metallic alphanumeric identification, keyed to the Posted O&M Instructions.
- b. Audible and visual notification appliances mounted on the exterior of the building, within unconditioned spaces, or in the vicinity of showers must be listed weatherproof appliances installed on weatherproof backboxes.
- c. Speakers must not be located in close proximity to the FACU or LOC so as to cause feedback when the microphone is in use.

3.2.5 Smoke and Heat Detectors

Locate detectors as required by NFPA 72 and their listing on a 4-inch mounting box. Install heat detectors not less than 4 inches from a side wall to the near edge. Heat detectors located on the wall must have the top of the detector at least 4 inches below the ceiling, but not more than 12 inches below the ceiling. Smoke detectors are permitted to be on the wall no lower than 12 inches from the ceiling with no minimum distance from the ceiling. Install smoke detectors no closer than 3 feet from air handling supply diffusers. Detectors installed in acoustical ceiling tiles must be centered in the tiles plus or minus 2 inches. Provide remote test switch and LED indicators for duct smoke detectors, located at maximum 7' above finished floor. Provide engraved plastic or metallic alphanumeric identification, keyed to the Posted O&M Instructions. Install spot type heat detectors in the hangar bay per NFPA 72, with maximum distance between detectors of 40 feet. At Contractor's option, linear heat detection may be provided in the hangar bays instead of spot heat detection. Install linear heat detection at maximum 30 foot spacing, and use the manufacturer's approved testing method to verify the detector's response setting after installation.

3.2.6 Carbon Monoxide Detectors

Locate detectors as required by NFPA 72 and their listings on a 4-inch mounting box. Carbon monoxide detectors must be installed separate from smoke and/or heat detectors. Provide engraved plastic or metallic alphanumeric identification, keyed to the Posted O&M Instructions.

3.2.7 Remote Annunciator

Locate the remote annunciator as shown on the drawings. Mount the

annunciator recessed, with the top 6 feet above the finished floor or center the annunciator at 5 feet, whichever is lower.

3.2.8 Local Operating Console (LOC)

Locate the LOC(s) as required by NFPA 72 and as indicated. Mount the console so that the top message button and microphone is no higher than 4 feet above the floor and the bottom (lowest) message button and microphone is at least 3 feet above the finished floor.

3.2.9 Ceiling Bridges

Provide ceiling bridges for ceiling-mounted appliances. Ceiling bridges must be as recommended/required by the manufacturer of the ceiling-mounted notification appliance.

3.3 SYSTEM FIELD WIRING

3.3.1 Wiring within Cabinets, Enclosures, and Boxes

Provide wiring installed in a neat and workmanlike manner and installed parallel with or at right angles to the sides and back of any box, enclosure, or cabinet. Conductors that are terminated, spliced, or otherwise interrupted in any enclosure, cabinet, mounting, or junction box must be connected to screw-type terminal blocks. Mark each terminal in accordance with the wiring diagrams of the system. The use of wire nuts or similar devices is prohibited. Wiring to conform with NFPA 70. Wiring in the hangar bay shall be per the hazardous classification identified on the drawings, and suitable for directed hose stream type wet location per NFPA 70. Connect to fire alarm devices and appliances from the bottom, and provide conduit drains.

Indicate the following in the wiring diagrams:

- a. Point-to-point wiring diagrams showing the points of connection and terminals used for electrical field connections in the system, including interconnections between the equipment or systems that are supervised or controlled by the system. Diagrams must show connections from field devices to the FACU and remote fire alarm/mass notification control units, initiating circuits, switches, relays and terminals.
- b. Complete riser diagrams indicating the wiring sequence of devices and their connections to the control equipment. Include a color code schedule for the wiring. Include floor plans showing the locations of devices and equipment.

3.3.2 Terminal Cabinets

Provide a terminal cabinet at the base of any circuit riser, on each floor at each riser, and where indicated on the drawings. Terminal size must be appropriate for the size of the wiring to be connected. Conductor terminations must be labeled and a drawing containing conductors, their labels, their circuits, and their interconnection must be permanently mounted in the terminal cabinet. Minimum size is 8 inches by 8 inches. Only screw-type terminals are permitted. Provide an identification label, that displays "FIRE ALARM TERMINAL CABINET" with 2-inch lettering, on the front of the terminal cabinet.

3.3.3 Alarm Wiring

- a. Voltages must not be mixed in any junction box, housing or device, except those containing power supplies and control relays.
- b. Utilize shielded wiring where recommended by the manufacturer. For shielded wiring, ground the shield at only one point, in or adjacent to the FACU.
- c. Pigtail or T-tap connections to signal line circuits, initiating device circuits, supervisory alarm circuits, and notification appliance circuits are prohibited.
- d. Color coding is required for circuits and must be maintained throughout the circuit. Conductors used for the same functions must be similarly color coded. Conform wiring to NFPA 70.
- e. Pull all conductors splice free. The use of wire nuts, crimped connectors, or twisting of conductors is prohibited. Where splices are unavoidable, the location of the junction box or pull box where they occur must be identified on the as-built drawings. The number and location of splices must be subject to approval by the Designated Fire Protection Engineer (DFPE).

3.3.4 Back Boxes and Conduit

In addition to the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM, provide all wiring in rigid metal conduit or intermediate metal conduit unless specifically indicated otherwise. Minimum conduit size must be 3/4-inch in diameter. Do not use electrical non-metallic tubing (ENT) or flexible non-metallic tubing and associated fittings.

- a. Galvanized rigid steel (GRS) conduit must be utilized where exposed to weather, where subject to physical damage, and where exposed on exterior of buildings. Intermediate metal conduit (IMC) may be used in lieu of GRS as allowed by NFPA 70.
- b. Electrical metallic tubing (EMT) is permitted above suspended ceilings or exposed where not subject to physical damage. Do not use EMT underground, encased in concrete, mortar, or grout, in hazardous locations, where exposed to physical damage, or outdoors. Use die-cast compression connectors.
- c. For rigid metallic conduit (RMC), only threaded type fitting are permitted for wet or damp locations.
- d. Flexible metal conduit is permitted for initiating device circuits 6 feet in length or less. Flexible metal conduit is prohibited for notification appliance circuits and signaling line circuits. Use liquid tight flexible metal conduit in damp and wet locations.
- e. Schedule 40 (minimum) polyvinyl chloride (PVC) is permitted where conduit is routed underground or underground below floor slabs. Convert non-metallic conduit, other than PVC Schedule 40 or 80, to plastic-coated rigid, or IMC, steel conduit before turning up through floor slab.
- f. Exterior wall penetrations must be weathertight. Conduit must be sealed to prevent the infiltration of moisture.

3.3.5 Conductor Terminations

Labeling of conductors at terminal blocks in terminal cabinets, FACU and the LOC must be provided at each conductor connection. Each conductor or cable must have a heat-shrink-wrap label to provide a unique and specific designation. Each terminal cabinet, FACU, and remote FACU must contain a laminated drawing that indicates each conductor, its label, circuit, and terminal. The laminated drawing must be neat, using 12 point lettering minimum size, and mounted within each cabinet, control unit, or unit so that it does not interfere with the wiring or terminals. Maintain existing color code scheme where connecting to existing equipment.

3.4 FIRESTOPPING

Provide firestopping for holes at conduit penetrations through floor slabs, fire-rated walls, partitions with fire-rated doors, corridor walls, and vertical service shafts in accordance with Section 07 84 00 FIRESTOPPING.

Firestopping shall be performed by the approved firestopping installer specified in 07 84 00, per approved designs and shop drawings.

3.5 PAINTING

- a. In unfinished areas (including areas above drop ceilings), paint all exposed electrical conduit (serving fire alarm equipment), fire alarm conduit, surface metal raceway, junction boxes and covers red. In lieu of painting conduit, the contractor may utilize red conduit with a factory applied finish.
- b. In finished areas, paint exposed electrical conduit (serving fire alarm equipment), fire alarm conduit, surface metal raceways, junction boxes, and electrical boxes to match adjacent finishes. The inside cover of the junction box must be identified as "Fire Alarm" and the conduit must have painted red bands 3/4-inch wide at 10-foot centers and at each side of a floor, wall, or ceiling penetration.
- c. Painting must comply with Section 09 90 00 PAINTS AND COATINGS.

3.6 FIELD QUALITY CONTROL

3.6.1 Test Procedures

Submit detailed test procedures, prepared and signed by the NICET Level IV Fire Alarm Technician, and the representative of the installing company, and reviewed by the QFPE minimum 60 calendar days prior to performing system tests. Detailed test procedures must list all components of the installed system such as initiating devices and circuits, notification appliances and circuits, signaling line devices and circuits, control devices/equipment, batteries, transmitting and receiving equipment, power sources/supply, annunciators, special hazard equipment, emergency communication equipment, interface equipment, and surge protective devices. Test procedures must include sequence of testing, time estimate for each test, and sample test data forms. The test data forms must be in a check-off format (pass/fail with space to add applicable test data; similar to the forma in NFPA 72 and NFPA 4.) The test procedures and accompanying test data forms must be used for the pre-Government testing and the Government testing. The test data forms must record the test

results and must:

- a. Identify the NFPA Class of all Initiating Device Circuits (IDC), and Notification Appliance Circuits (NAC), Voice Notification System Circuits (NAC Audio), and Signaling Line Circuits (SLC).
- b. Identify each test required by NFPA 72 Test Methods and required test herein to be performed on each component, and describe how these tests must be performed.
- c. Identify each component and circuit as to type, location within the facility, and unique identity within the installed system. Provide necessary floor plan sheets showing each component location, test location, and alphanumeric identity.
- d. Identify all test equipment and personnel required to perform each test (including equipment necessary for smoke detector testing. The use of magnets is not permitted.
- e. Provide space to identify the date and time of each test. Provide space to identify the names and signatures of the individuals conducting and witnessing each test.

3.6.2 Pre-Government Testing

3.6.2.1 Verification of Compliant Installation

Conduct inspections and tests to ensure that devices and circuits are functioning properly. Tests must meet the requirements of paragraph entitled "Minimum System Tests" as required by NFPA 72. The contractor and an authorized representative from each supplier of equipment must be in attendance at the pre-Government testing to make necessary adjustments. After inspection and testing is complete, provide a signed Verification of Compliant Installation letter by the QFPE that the installation is complete, compliant with the specification and fully operable. The letter must include the names and titles of the witnesses to the pre-Government tests. Provide all completion documentation as required by NFPA 72 including all referenced annex sections and the test reports noted below.

- a. NFPA 72 Record of Completion.
- b. NFPA 72 Record of Inspection and Testing.
- c. Fire Alarm and Emergency Communication System Inspection and Testing Form.
- d. Audibility test results with marked-up test floor plans.
- e. Intelligibility test results with marked-up floor plans.
- f. Documentation that all tests identified in the paragraph "Minimum System Tests" are complete.

3.6.2.2 Request for Government Final Test

When the verification of compliant installation has been completed, submit a formal request for Government final test to the Designated Fire Protection Engineer (DFPE) and Contracting Officer's Representative (COR).

Government final testing will not be scheduled until the DFPE has received copies of the request for Government final testing and Verification of Compliant Installation letter with all required reports. Government final testing will not be performed until after the connections to the installation-wide fire reporting system have been completed and tested to confirm communications are fully functional. Submit request for test at least 15 calendar days prior to the requested test date.

3.6.3 Correction of Deficiencies

If equipment was found to be defective or non-compliant with contract requirements, perform corrective actions and repeat the tests. Tests must be conducted and repeated if necessary until the system has been demonstrated to comply with all contract requirements.

3.6.4 Government Final Tests

The tests must be performed in accordance with the approved test procedures in the presence of the DFPE. Furnish instruments and personnel required for the tests. The following must be provided at the job site for Government Final Testing:

- a. The manufacturer's technical representative.
- b. The contractor's Qualified Fire Protection Engineer (QFPE).
- c. Marked-up red line drawings of the system as actually installed.
- d. Loop resistance test results.
- e. Complete program printout including input/output addresses.
- f. Copy of pre-Government Test Certificate, test procedures and completed test data forms.
- g. Audibility test results with marked-up floor plans.
- h. Intelligibility test results with marked-up floor plans.

Government Final Tests will be witnessed by the Designated Fire Protection Engineer, Contracting Officer's Representative (COR) and the Contractor's Qualified Fire Protection Engineer (QFPE). At this time, any and all required tests noted in the paragraph "Minimum System Tests" must be repeated at their discretion. If changes are made to the system following publication of the preliminary test report or failure of final testing occurs, perform reacceptance testing per NFPA 72, update test reports, O&M Instructions, point lists and other closeout documentation. Time and travel expenses incurred by the COR, AHJ and their representatives due to failed final testing or reacceptance testing must be reimbursed by the Contractor.

3.7 MINIMUM SYSTEM TESTS

3.7.1 System Tests

Test the system in accordance with the procedures outlined in NFPA 72. The required tests are as follows:

- a. Loop Resistance Tests: Measure and record the resistance of each

circuit with each pair of conductors in the circuit short-circuited at the farthest point from the circuit origin. The tests must be witnessed by the Contracting Officer and test results recorded for use at the final Government test.

- b. Verify the absence of unwanted voltages between circuit conductors and ground. The tests must be accomplished at the pre-Government test with results available at the final system test.
- c. Verify that the control unit is in the normal condition as detailed in the manufacturer's O&M manual.
- d. Test each initiating device and notification appliance and circuit for proper operation and response at the control unit. Smoke detectors must be tested in accordance with manufacturer's recommended calibrated test method. Use of magnets is prohibited. Testing of duct smoke detectors must comply with the requirements of NFPA 72 except disconnect at least 20 percent of devices. If there is a failure at these devices, then supervision must be tested at each device.
- e. Carbon Monoxide Detector Tests: Carbon monoxide detectors must be tested in accordance with NFPA 72 and the manufacturer's recommended calibrated test method.
- f. Test the system for specified functions in accordance with the contract drawings and specifications and the manufacturer's O&M manual.
- g. Test both primary power and secondary power. Verify, by test, the secondary power system is capable of operating the system for the time period and in the manner specified.
- h. Determine that the system is operable under trouble conditions as specified.
- i. Visually inspect wiring.
- j. Test the battery charger and batteries.
- k. Verify that software control and data files have been entered or programmed into the FACU. Hard copy records of the software must be provided to the Contracting Officer.
- l. Verify that red-line drawings are accurate.
- m. Measure the current in circuits to ensure there is the calculated spare capacity for the circuits.
- n. Measure voltage readings for circuits to ensure that voltage drop is not excessive.
- o. Disconnect the verification feature for smoke detectors during tests to minimize the amount of smoke needed to activate the sensor. Testing of smoke detectors must be conducted using real smoke or the use of canned smoke which is permitted.
- p. Measure the voltage drop at the most remote appliance (based on wire length) on each notification appliance circuit.
- q. Verify the documentation cabinet is installed and contains all

as-built shop drawings, product data sheets, design calculations, site-specific software data package, and all documentation required by paragraph titled "Test Reports".

3.7.2 Audibility Tests

Sound pressure levels from audible notification appliances must be a minimum of 15 dBA over ambient with a maximum of 110 dBA in any occupiable area. The provisions for audible notification (audibility and intelligibility) must be met with doors, fire shutters, movable partitions, and similar devices closed.

3.7.3 Intelligibility Tests

Intelligibility testing of the System must be accomplished in accordance with NFPA 72 for Voice Evacuation Systems, and ASA S3.2. Following are the specific requirements for intelligibility tests:

- a. Intelligibility Requirements: Verify intelligibility by measurement after installation.
- b. Ensure that a CIS value greater than the required minimum value is provided in each area where building occupants typically could be found. The minimum required value for CIS is 0.8. Rounding of values is permitted.
- c. Areas of the building provided with hard wall and ceiling surfaces (such as metal or concrete) that are found to cause excessive sound reflections may be permitted to have a CIS score less than the minimum required value if approved by the DFPE, and if building occupants in these areas can determine that a voice signal is being broadcast and they must walk no more than 33 feet to find a location with at least the minimum required CIS value within the same area.
- d. Areas of the building where occupants are not expected to be normally present are permitted to have a CIS score less than the minimum required value if personnel can determine that a voice signal is being broadcast and they must walk no more than 50 feet to a location with at least the minimum required CIS value within the same area.
- e. Take measurements near the head level applicable for most personnel in the space under normal conditions (e.g., standing, sitting, sleeping, as appropriate).
- f. The distance the occupant must walk to the location meeting the minimum required CIS value must be measured on the floor or other walking surface as follows:
 - (1) Along the centerline of the natural path of travel, starting from any point subject to occupancy with less than the minimum required CIS value.
 - (2) Curving around any corners or obstructions, with a 12 inches clearance there from.
 - (3) Terminating directly below the location where the minimum required CIS value has been obtained.

Use commercially available test instrumentation to measure intelligibility

as specified by NFPA 72 as applicable. Use the mean value of at least three readings to compute the intelligibility score at each test location.

3.8 SYSTEM ACCEPTANCE

Following acceptance of the system, as-built drawings and O&M manuals must be delivered to the Contracting Officer for review and acceptance. The drawings must show the system as installed, including deviations from both the project drawings and the approved shop drawings. These drawings must be submitted within two weeks after the final Government test of the system. At least one set of as-built (marked-up) drawings must be provided at the time of, or prior to the Final Government Test.

- a. The drawings must be prepared electronically and sized no less than the contract drawings. Furnish one set of CDs or DVDs containing software back-up and CAD based drawings in latest version of AutoCAD, DXF and portable document formats of as-built drawings and schematics.
- b. Include complete wiring diagrams showing connections between devices and equipment, both factory and field wired.
- c. Include a riser diagram and drawings showing the as-built location of devices and equipment.
- d. Provide Operation and Maintenance (O&M) Instructions. Include Posted O&M instructions, aluminum framed behind glass showing a floor plan with all devices, secure areas, fire barriers. Include point list with all addresses, types and legends, wiring diagrams and schematics, equipment schedule. Instructions shall be weatherproof with professionally prepared graphics, printed on full size sheets in color. O&M Instructions shall be keyed to the device identification.

3.9 INSTRUCTION OF GOVERNMENT EMPLOYEES

3.9.1 Instructor

Provide the services of an instructor, who has received specific training from the manufacturer for the training of other persons regarding the operation, inspection, testing, and maintenance of the system provided. The instructor must train the Government employees designated by the Contracting Officer, in the care, adjustment, maintenance, and operation of the fire alarm system. The instructor must be thoroughly familiar with all parts of this installation. The instructor must be trained in operating theory as well as in practical O&M work. Submit the instructors information and qualifications including the training history.

3.9.2 Required Instruction Time

Provide 16 hours of instruction after final acceptance of the system. The instruction must be given during regular working hours on such dates and times selected by the Contracting Officer. The instruction may be divided into two or more periods at the discretion of the Contracting Officer. The training must allow for rescheduling for unforeseen maintenance and/or fire department responses.

3.9.3 Technical Training Manual

Provide, in manual format, lesson plans, operating instructions, maintenance procedures, and training data for the training courses. The

operations training must familiarize designated government personnel with proper operation of the installed system. The maintenance training course must provide the designated government personnel adequate knowledge required to diagnose, repair, maintain, and expand functions inherent to the system.

3.10 EXTRA MATERIALS

3.10.1 Repair Service/Replacement Parts

Repair services and replacement parts for the system must be available for a period of 10 years after the date of final acceptance of this work by the Contracting Officer. During the warranty period, the service technician must be on-site within 24 hours after notification. All repairs must be completed within 24 hours of arrival on-site.

During the warranty period, the installing fire alarm contractor is responsible for conducting all required testing and maintenance in accordance with the requirements and recommended practices of NFPA 72 and the system manufacturer. Installing fire alarm contractor is NOT responsible for any damage resulting from abuse, misuse, or neglect of equipment by the end user.

3.10.2 Spare Parts

Spare parts furnished must be directly interchangeable with the corresponding components of the installed system. Spare parts must be suitably packaged and identified by nameplate, tagging, or stamping. Spare parts must be delivered to the Contracting Officer at the time of the Government testing and must be accompanied by an inventory list.

3.10.3 Document Storage Cabinet

Upon completion of the project, but prior to project close-out, place in the document storage cabinet copies of the following record documentation:

- a. As-built shop drawings
- b. Product data sheets
- c. Design calculations
- d. Site-specific software data package
- e. All documentation required by SD-06.

-- End of Section --

Preliminary & Final Hangar Fire Suppression/Detection Acceptance Testing (PAT & FAT)

Testing

At a minimum, provide the testing and reports outlined in this section as relevant to the Scope of Work. Coordinate testing personnel as required to demonstrate the coordination and communication of the fire protection systems through full functional testing. Independent testing of each individual fire protection system is not a substitute to the functional testing requirements.

Testing Personnel

Provide a Fire Protection Engineer (FPE) meeting the requirements of UFC 3-600-01 for the witnessing and/or review of testing/reports as outlined in this section. There shall be one or more FPE's responsible for fire alarm, fire suppression and life safety matters.

At a minimum, provide a factory authorized representative for the startup and/or testing of the following systems as outlined below:

- Fire Suppression System (Preliminary and Final Testing)
- Fire Alarm and Mass Notification System (FACU/ACU) (Preliminary and Final Testing)
- Releasing Service Fire Alarm Control Unit (RSFACU) (Preliminary and Final Testing)
- Provide a testing plan certified by the FPE(s) that at a minimum includes the following:
 - Who will perform the testing and who will be the onsite factory authorized representatives.
 - As a minimum the following personnel are required to be present:
 - Prime Contractor
 - Fire Protection Engineer(s)
 - Aboveground pipe Installer
 - Fire Suppression System Installer (NICET)
 - Fire Alarm Installer (NICET)
 - Manufacture's Representatives
 - HVAC (for duct detection)
 - What are the safety precautions taken during testing.

Preliminary Testing

Provide acceptance testing for the fire suppression and fire alarm systems complying with **NFPA 4**, NFPA 13, 24, and 72 as applicable. At a minimum, provide the following preliminary testing reports signed by the FPE(s).

Preliminary & Final Hangar Fire Suppression/Detection Acceptance Testing (PAT & FAT)

- Contractor's Material and Test Certificate for Aboveground Piping per NFPA 13 for each riser, manifold, and fire department connection. (Reviewed by the FPE)
- System record of Inspection and Testing, Notification appliance supplementary Record of Inspection and Testing, Initiating Device Supplementary Record of Inspection and Testing, Interface Component Supplementary Record of Inspection and Testing, and Mass Notification System Supplementary Record of Inspection and Testing per NFPA 72 for the FACU and RSFACU. (Reviewed by the FPE)
- Test the mass notification system in accordance with the requirements of UFC 4-021-01. At a minimum provide sound power levels (Decibel A Weighted Scale (dbA)) and intelligibility scores (CIS) throughout the facility. Submit drawing or table indicating dbA levels and CIS scores throughout each space. (Witnessed by the FPE)
- Circuit Integrity Testing (open, short, ground IAW NFPA 72) (Witnessed by the FPE)
- Demonstrate the functionality of the fire alarm system is in compliance with the FACU and RFSACU functional matrixes. (Witnessed by the FPE)

Request for Final Testing

Provide a break-in period of at least 14 consecutive days after the FACU and RSFACU have been enabled, prior to any final testing. Provide a written request for a final test from the FPE(s), after preliminary testing is complete, adjustments have been made to the system, and the system is ready for service.

Final Testing

Final testing to be witnessed by the AHJ, as defined by UFC 1-200-01. (E.g. For an Air Force project the AHJ is the Air Force Civil Engineer Center, Operations Director (AFCEC/CO), even if the project is constructed by NAVFAC or the Army Corps of Engineers. AFCEC/CO would witness final testing in this example.) The final testing may be witnessed by an in writing delegated representative at the discretion of the AHJ. With the exception of system flushing, and

Preliminary & Final Hangar Fire Suppression/Detection Acceptance Testing (PAT & FAT)

hydrostatic testing repeat preliminary tests during the final testing at the discretion of the AHJ. Correct system failures or other deficiencies identified during the final testing and retest in the presence of the AHJ, at their discretion.

Final Testing Sequence of Events

AFCEC/CO FPE or their in-writing designated FPE will be on site to witness all FAT's. The following procedure of events can be expected.

- 48 hours before the beginning of the FAT contractor shall turn off all AC power to all fire alarm components including but not limited to FACU, RSFACU, NAC's, AMPS and Transmitter
- Contractor led safety briefing
- 15 minute FACU/RSFACU activation battery test. Include all solenoids designed to operate within a fire area.
- dbA and intelligibility tests.
- Plastic or other protective measures that may alter the acoustics or visual reflectivity of the hangar bay may not be hung before this point.
- FACU/RSFACU Alarm Matrix Testing
 - Fire alarm/suppression device circuit integrity testing (opens, shorts, and grounds)
 - Initiating devices (flow and tamper switches, detectors, pull stations, etc.)
- General review of the fire alarm system/MNS for proper installation
- General review of the fire sprinkler system for proper installation
- General review of the life safety (exits, ratings, etc.) systems for proper installation

The following are done at the PAT only with appropriate witnessing of the Government (COR, COE, Base CE, Fire Department, etc).

- 60 minute MNS test
- Hydrostatic testing
- Emergency lighting

SECTION 31 00 00

EARTHWORK
08/23

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
(AASHTO)

AASHTO T 180 (2017) Standard Method of Test for
Moisture-Density Relations of Soils Using
a 4.54-kg (10-lb) Rammer and a 457-mm
(18-in.) Drop

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C600 (2017) Installation of Ductile-Iron Mains
and Their Appurtenances

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M (2020; Errata 1 2021) Structural Welding
Code - Steel

ASTM INTERNATIONAL (ASTM)

ASTM C33/C33M (2023) Standard Specification for Concrete
Aggregates

ASTM C117 (2023) Standard Test Method for Materials
Finer than 75-um (No. 200) Sieve in
Mineral Aggregates by Washing

ASTM C136/C136M (2019) Standard Test Method for Sieve
Analysis of Fine and Coarse Aggregates

ASTM D1140 (2017) Standard Test Methods for
Determining the Amount of Material Finer
than 75-µm (No. 200) Sieve in Soils by
Washing

ASTM D1556/D1556M (2015; E 2016) Standard Test Method for
Density and Unit Weight of Soil in Place
by Sand-Cone Method

ASTM D1557 (2012; E 2015) Standard Test Methods for
Laboratory Compaction Characteristics of
Soil Using Modified Effort (56,000
ft-lbf/ft³) (2700 kN-m/m³)

ASTM D2216 (2019) Standard Test Methods for

Laboratory Determination of Water
(Moisture) Content of Soil and Rock by Mass

ASTM D2487	(2017; E 2020) Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D2974	(2020; E 2020) Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
ASTM D4253	(2016; E 2019) Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
ASTM D4254	(2016) Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
ASTM D4318	(2017; E 2018) Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D4829	(2021) Standard Test Method for Expansion Index of Soils
ASTM D6938	(2017a) Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
ASTM D8167/D8167M	(2023) Standard Test Method for In-Place Bulk Density of Soil and Soil-Aggregate by a Low-Activity Nuclear Method (Shallow Depth)

U.S. ARMY CORPS OF ENGINEERS (USACE)

EM 385-1-1	(2024) Safety -- Safety and Health Requirements Manual
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U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA 600/4-79/020	(1983) Methods for Chemical Analysis of Water and Wastes
EPA SW-846.3-3	(1999, Third Edition, Update III-A) Test Methods for Evaluating Solid Waste: Physical/Chemical Methods

1.2 DEFINITIONS

1.2.1 Structural Fill

Soil material placed to support buildings, walls, pads, and other similar facilities.

1.2.2 Embankment Fill

Soil material placed to construct embankment.

1.2.3 Porous Fill

Free-draining material placed for subsurface drainage, as a capillary break, or another specific purpose.

1.2.4 Topsoil

Surface layer of primarily organic soil capable of supporting vegetation growth.

1.2.5 Utility Bedding Material

Fill placed to directly support pipes, conduits, cables, and appurtenant structures. Bedding may also be used to provide a cushion between utilities and bedrock, obstacles, obstructions and other unyielding materials.

1.2.6 Satisfactory Materials

Satisfactory materials for fill, backfill, and/or any in-situ soils to remain in place comprise any materials classified by ASTM D2487 as GW, GP, GM, GP-GM, GW-GM, GC, GP-GC, GM-GC, SW, SP. Maximum particle size to be no greater than 2 inches in any dimension.

1.2.7 Unsatisfactory Materials

Materials which do not comply with the requirements for satisfactory materials are unsatisfactory. Unsatisfactory materials also include man-made fills; trash; refuse; backfills from previous construction; roots and other organic matter or frozen material. Notify the Contracting Officer when encountering any contaminated materials.

1.2.8 Cohesionless Materials

Cohesionless materials include materials classified in ASTM D2487 as GW, GP, SW, and SP. Materials classified as GM and SM will be identified as cohesionless only when the fines are nonplastic. Perform testing, required for classifying materials, in accordance with ASTM D4318, ASTM C117, ASTM C136/C136M and ASTM D1140.

1.2.9 Cohesive Materials

Cohesive materials include materials classified as GC, SC, ML, CL, MH, and CH. Materials classified as GM and SM will be identified as cohesive only when the fines are plastic. Perform testing, required for classifying materials, in accordance with ASTM D4318, ASTM C117, ASTM C136/C136M and ASTM D1140.

1.2.10 Hard/Unyielding Materials

Hard/Unyielding materials comprise weathered rock, dense consolidated deposits, or conglomerate materials which are not included in the definition of "rock" with stones greater than 3 inch in any dimension or as defined by the pipe manufacturer, whichever is smaller. These materials usually require the use of heavy excavation equipment, ripper

teeth, or jack hammers for removal.

1.2.11 Unstable Material

Unstable materials are too weak to adequately support the utility pipe, conduit, equipment, or appurtenant structure. Satisfactory material may become unstable due to ineffective drainage, dewatering, becoming frozen, excessive loading.

1.2.12 Expansive Soils

Expansive soils are defined as soils that have an expansion index greater than 20 when tested in accordance with ASTM D4829.

1.2.13 Rock

Solid homogeneous interlocking crystalline material with firmly cemented, laminated, or foliated masses or conglomerate deposits, neither of which can be removed without systematic drilling and blasting, drilling and the use of expansion jacks or feather wedges, or the use of backhoe-mounted pneumatic hole punchers or rock breakers; also large boulders, buried masonry, or concrete other than pavement exceeding 1/2 cubic yard in volume. Removal of hard material will not be considered rock excavation because of intermittent drilling and blasting that is performed merely to increase production.

1.2.14 Capillary Water Barrier

A layer of clean, poorly graded crushed rock, stone, or natural sand or gravel having a high porosity which is placed beneath a building slab with or without a vapor barrier to cut off the capillary flow of pore water to the area immediately below a slab.

1.2.15 Degree of Compaction (Proctor)

Degree of compaction required, except as noted in the second sentence, is expressed as a percentage of the maximum density obtained by the test procedure presented in ASTM D1557 abbreviated as a percent of laboratory maximum density. Since ASTM D1557 applies only to soils that have 30 percent or less by weight of their particles retained on the 3/4 inch sieve, express the degree of compaction for material having more than 30 percent by weight of their particles retained on the 3/4 inch sieve as a percentage of the maximum density in accordance with AASHTO T 180-21 paragraph 1.5, Note 1.

1.2.16 Degree of Compaction (Relative Density)

Degree of compaction required for soils with less than 5 percent passing the No. 200 sieve, is expressed as a relative percentage of the maximum index density/dry unit weight and minimum index density/dry unit weight, obtained by the test procedures in accordance with ASTM D4253 and ASTM D4254, respectively, abbreviated as a percent of laboratory relative density.

1.2.17 Borrow

Soil brought to the project site from an external location for the purposes of project construction.

1.2.18 Subgrade

Earth materials directly below foundations and directly below granular base materials in building slab and pavement areas including shoulders.

1.3 SUBSURFACE DATA

Subsurface soil boring logs in the general vicinity of the project area are available upon request.

1.4 CRITERIA FOR BIDDING

Base bids on the following criteria:

- a. Surface elevations are as indicated.
- b. Pipes or other artificial obstructions, except those indicated, will not be encountered.
- c. Ground water elevations indicated by the boring log were those existing at the time subsurface investigations were made and do not necessarily represent ground water elevation at the time of construction.
- d. Ground water was encountered at 26.0 feet during drilling.
- e. Material character is indicated by the boring logs.
- f. Hard materials and rock should not be encountered.

1.5 SUBMITTALS

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Excavation and Trenching Plan; G

Jacking, Boring, and Tunneling Plan; G

Disposition of Surplus Materials; G

Preconstruction Meeting; G

SD-06 Test Reports

Material Test Report; G

Borrow Site Testing; G

Pipe Inspection Report; G

1.6 QUALITY CONTROL

1.6.1 Qualified Technician

Provide a Qualified Technician to inspect, monitor, sample, and performing field testing. The technician qualifications need to be one of the following: a current National Institute for Certification in Engineering Technologies (NICET) Level II minimum certification in Construction Materials Testing Soils; a Geologist-in-Training with minimum one-year experience; an Engineer-in-Training with minimum one-year experience; a Registered Geologist; or a Professional Engineer.

1.6.2 Lab Validation

Perform testing by a Corps validated commercial testing laboratory or Contractor established testing laboratory meeting the requirements of Section 01 45 00 (or similar number) entitled QUALITY CONTROL and approved by the Contracting Officer. Submit testing laboratory validation for the testing to be performed. Do not permit work requiring testing until testing facilities have been inspected, Corps validated and approved by the Contracting Officer.

1.6.3 Preconstruction Meeting

Conduct a preconstruction meeting at the jobsite at least five business days prior to the start of earthwork operations on the project. The preconstruction meeting is to be arranged by the Contractor and is to follow the written agenda submitted prior to the meeting. The purpose of this meeting is to review the requirements of this specification and the associated plans. The following individuals must be in attendance at this meeting: Contractor's Project Manager and Project Superintendent, earthwork subcontractor's Project Manager and Site Foreman, Contractor's Geotechnical Engineer and Testing Agency, Government Geotechnical Engineer and Civil Engineer, and Government Construction Manager and Engineering Technician.

The minutes of this meeting are to be recorded by the Contractor and published via email within 48 hours to all attendees. The minutes must be re-published within 48 hours via email pending any subsequent comments from the attendees.

PART 2 PRODUCTS

2.1 SOIL MATERIALS

2.1.1 Structural Fill

Materials classified as GW, GP,GM, GC, GW-GM, GW-GC, GP-GM, GP-GC, GC-GM, SW, or SP in accordance with ASTM D2487. Select material type appropriate for the intended purpose.

2.1.2 Embankment Fill

Materials classified as GW, GP, GM, GC, GW-GM, GW-GC, GP-GM, GP-GC, GC-GM, SW, SP,SW-SM,SW-SC in accordance with ASTM D2487. Select material type appropriate for the intended purpose.

2.1.3 Porous Fill

Materials containing less than 5 percent passing the No. 200 sieve. Provide the gradation as appropriate for the intended purpose.

2.1.4 Topsoil

Material suitable for topsoil is defined as: Natural, friable soil representative of productive, well-drained soils in the area, free of subsoil, stumps, rocks larger than one inch diameter, brush, weeds, toxic substances, and other material detrimental to plant growth. Amend topsoil pH range to obtain a pH of 5.5 to 7.

2.1.5 Capillary Water Barrier

Conform to ASTM C33/C33M for fine aggregate grading with a maximum of 3 percent by weight passing ASTM D1140, No. 200 sieve or 1-1/2 inch and no more than 2 percent by weight passing the No. 4 size sieve.

2.1.6 Utility Bedding Material

Except as specified otherwise in the individual piping section, provide bedding for buried piping in accordance with AWWA C600. Install bedding for plastic piping to spring line of pipe. Provide geotextile fabric below bedding layer where indicated. Utility bedding material may include the following:

2.1.6.1 Class I

Angular, 0.25 to 1.5 inch, graded stone, including a number of fill materials that have regional significance such as coral, slag, cinders, crushed stone, and crushed shells.

2.1.6.2 Class II

Coarse sands and gravels with maximum particle size of 1.5 inch, including various graded sands and gravels containing small percentages of fines, generally granular and noncohesive, either wet or dry. Soil Types GW, GP, SW, and SP are included in this class as specified in ASTM D2487.

2.1.6.3 Sand

Clean, coarse-grained sand classified as SW by ASTM D2487 for bedding and backfill as indicated.

2.1.6.4 Gravel and Crushed Stone

Clean, coarsely graded natural gravel, crushed stone or a combination thereof identified as GW or GP in accordance with ASTM D2487 for bedding and backfill as indicated. Do not exceed maximum particle size of 3 inches.

2.2 BURIED WARNING AND IDENTIFICATION MARKERS

Provide metallic core or metallic-faced, acid- and alkali-resistant, polyethylene plastic warning tape manufactured specifically for warning and identification of buried utility lines. Provide tape on rolls, 3 inches minimum width, color coded as specified below for the intended utility with warning and identification imprinted in bold black letters continuously over the entire tape length. Warning and identification to

read, "CAUTION, BURIED (intended service) LINE BELOW" or similar wording. Provide permanent color and printing, unaffected by moisture or soil.

Warning Tape Color Codes	
Red	Electric
Yellow	Gas, Oil; Dangerous Materials
Orange	Telephone and Other Communications
Blue	Water Systems
Green	Sewer Systems
White	Steam Systems
Gray	Compressed Air

2.2.1 Warning Tape for Metallic Piping

Provide acid and alkali-resistant polyethylene plastic tape conforming to the width, color, and printing requirements specified above, with a minimum thickness of 0.003 inch and a minimum strength of 1500 psi lengthwise, and 1250 psi crosswise, with a maximum 350 percent elongation.

2.2.2 Detectable Warning Tape for Non-Metallic Piping

Provide polyethylene plastic tape conforming to the width, color, and printing requirements specified above, with a minimum thickness of 0.004 inch, and a minimum strength of 1500 psi lengthwise and 1250 psi crosswise. Manufacture tape with integral wires, foil backing, or other means of enabling detection by a metal detector when tape is buried up to 3 feet deep. Encase metallic element of the tape in a protective jacket or provide with other means of corrosion protection.

2.2.3 Detection Wire for Non-Metallic Piping

Insulate a single strand, solid copper detection wire with a minimum of 12 AWG.

PART 3 EXECUTION

3.1 PROTECTION

Perform all work specified in accordance with applicable requirements of the Corps of Engineers publication EM 385-1-1 Safety and Health Requirements Manual.

Use equipment of type and size appropriate for the site conditions (soil character and moisture content). Maintenance of exposed subgrades and fills is the responsibility of the Contractor. The Contractor is required to prevent damage by ineffective drainage, dewatering, and heavy loads and equipment by implementing precautionary measures. Repair or replace any defects or damage.

3.1.1 Underground Utilities

Location of the existing utilities indicated is approximate. Physically verify the location and elevation of the existing utilities indicated prior to starting construction. The Contractor is responsible for protecting utilities from damage during construction.

3.1.2 Drainage and Dewatering

Provide for the collection and disposal of surface and subsurface water encountered during construction.

3.1.3 Shoring and Sheeting

Submit an Excavation and Trenching Plan to stabilize features, prevent undermining or unintended horizontal and vertical movement of adjacent structures, and prevent slippage or movement in banks or slopes adjacent to the excavation. Submit drawings and calculations, certified by a registered professional engineer, describing the methods for shoring and sheeting of excavations. Drawings to include material sizes and types, arrangement of members, and the sequence and method of installation and removal. Calculations are to include data and references used.

3.1.4 Protection of Graded Surfaces

Protect newly backfilled, graded, and topsoiled areas from traffic, erosion, and settlements that may occur. Repair or reestablish damaged grades, elevations, or slopes.

3.2 BORROW

Select borrow material to meet the requirements and conditions of the fill or embankment for which it is to be used. Obtain borrow material from approved private sources. Unless otherwise provided in the contract, the Contractor is responsible for obtaining the right to procure material, pay royalties and other charges involved, and bear the expense of developing the sources, including rights-of-way for hauling from the owners. Unless specifically provided, do not obtain borrow within the limits of the project site without prior written approval.

3.2.1 Contractor Furnished Borrow Area(s)

Obtain approved borrow materials from approved offsite sources. If a borrow source is selected that is not a commercial entity from which soil material is directly purchased, submit a Borrow Plan that includes the borrow source location, geotechnical test results showing the fill material meets the Contract requirements, environmental test results in accordance with paragraph ENVIRONMENTAL REQUIREMENTS FOR OFF-SITE SOIL, and any Federal, State, and local permits required for excavation and reclamation of the borrow area.

3.2.2 Environmental Requirements for Off-Site Soil

Test offsite soils brought in for use as backfill for Total Petroleum Hydrocarbons (TPH), Benzene, Toluene, Ethyl Benzene, and Xylene (BTEX) and full Toxicity Characteristic Leaching Procedure (TCLP) including ignitability, corrosivity and reactivity. Backfill may not contain concentrations above 10 parts per million (ppm) of total petroleum hydrocarbons (TPH) and 10 ppm of the sum of Benzene, Toluene, Ethyl

Benzene, and Xylene (BTEX) and pass the TCPL test. Determine TPH concentrations by using EPA 600/4-79/020 Method 418.1. Determine BTEX concentrations by using EPA SW-846.3-3 Method 5030/8020/8260B. Perform TCLP in accordance with EPA SW-846.3-3 Method 1311. Perform hazardous waste characteristic tests for ignitability, corrosivity, and reactivity in accordance with accepted standard methods. Perform PCB testing in accordance with accepted standard methods for sampling and analysis of bulk solid samples. Provide borrow site testing for petroleum hydrocarbons and BTEX from a grab sample of material from the area most likely to be contaminated at the borrow site (as indicated by visual or olfactory evidence), with at least one test from each borrow site. Provide borrow site testing for hazardous waste characteristics (TPH, BTEX and TCLP) from a composite sample of material, collected in accordance with standard soil sampling techniques. Do not bring borrow material to project site until Borrow Plan containing environmental test results has been received and approved by the Contracting Officer.

3.3 SURFACE PREPARATION

3.3.1 Stripping

Strip existing surface materials to a depth of 4 inches below the existing ground surface. Strip in all areas within the planned limits of disturbance. All stripped materials not suitable for reuse as topsoil will be wasted. Screen all stripped soils to remove roots and organic materials prior disposal.

Strip suitable soil from the site where excavation or grading is indicated and stockpile separately from other excavated material. Protect topsoil and keep in segregated piles until needed.

3.3.2 Proof Rolling

Perform proof rolling on exposed subgrade that is unfrozen and free of surface water (wet conditions resulting from rainfall). Notify the Contracting Officer a minimum of three days prior to proof rolling. Perform proof rolling in the presence of the Contracting Officer.

After stripping, excavating, and rough grading to the planned elevation, proof roll the existing subgrade of all building, pavement and embankment locations with six passes of a loaded tandem axle dump truck. Operate the truck in a systematic manner to ensure the number of passes over all areas, and at speeds between 2.5 to 3.5 miles per hour. Subgrade materials that exhibit excessive deflection and/or rutting during proof rolling need to be scarified, aerated, and re-compacted to specified density at plus or minus 2 percent of optimum moisture content prior to being considered for remedial action by the Contracting Officer. When proof rolling under buildings, the building subgrade is considered to extend 5 feet beyond the building lines and make one-half of the passes with the roller in a direction perpendicular to the other passes.

3.3.3 Stockpiling Operations

Place and grade stockpiles of satisfactory and wasted materials as specified. Keep stockpiles in a neat and well drained condition, giving due consideration to drainage at all times. Clear, grub, and seal by rubber-tired equipment, the ground surface at stockpile locations; separately stockpile excavated satisfactory and unsatisfactory materials.

Protect stockpiles of satisfactory materials from contamination which may destroy the quality and fitness of the stockpiled material. Do not create stockpiles that could obstruct the flow of any stream, endanger a partly finished structure, impair the efficiency or appearance of any structure, or be detrimental to the completed work in any way. If the Contractor fails to protect the stockpiles, and any material becomes unsatisfactory, remove and replace such material with satisfactory material from approved sources.

3.4 EXCAVATION

Excavate to contours, elevation, and dimensions indicated. Excavate soil disturbed or weakened by Contractor's operations, and soils softened or made unstable for subsequent construction due to exposure to weather. Use material removed from excavations meeting the specified requirements in the construction of fills, embankments, subgrades, shoulders, bedding (as backfill), and for similar purposes to minimize surplus material and to minimize additional material to brought on site. Do not excavate below indicated depths except to remove unstable material as determined by the Government and confirmed by the Contracting Officer. Remove and replace excavations below the grades shown with appropriate materials as directed by the Contracting Officer.

If at any time during excavation, including excavation from borrow areas, the Contractor encounters material that may be classified as rock or as hard/unyielding material, uncover such material, and notify the Contracting Officer. Do not proceed with the excavation of this material until the Contracting Officer has classified the materials as common excavation or rock excavation. Failure on the part of the Contractor to uncover such material, notify the Contracting Officer, and allow sufficient time for classification and delineation of the undisturbed surface of such material will cause the forfeiture of the Contractor's right of claim to any classification or volume of material to be paid for other than that allowed by the Contracting Officer for the areas of work in which such deposits occur.

3.4.1 Ditches, Gutters, and Channel Changes

Finish excavation of ditches, gutters, and channel changes by cutting accurately to the cross sections, grades, and elevations shown. Do not excavate below grades shown. Backfill excessive excavation as directed by the Contracting Officer, with satisfactory, compacted, material or with suitable stone or cobble to grades shown. Dispose excavated material as shown or as directed. Do not allow material to be deposited within 4 feet from edge of a ditch. Maintain excavations free from detrimental quantities of leaves, brush, sticks, trash, and other debris until final acceptance of the work.

3.4.2 Trench Excavation Requirements

Excavate the trench as recommended by the manufacturer of the pipe to be installed. Slope trench walls below the top of the pipe, or make vertical, and of such width as recommended by the manufacturer. Provide vertical trench walls where no manufacturer installation instructions are available. Do not exceed the trench width of 24 inches below the top pipe plus pipe outside diameter (O.D.) for pipes of less than 24 inches inside diameter, and do not exceed 36 inches plus pipe outside diameter for pipe sizes larger than 24 inches inside diameter. Where recommended trench widths are exceeded, provide redesign, stronger pipe, or special

installation procedures. The Contractor is responsible for the cost of redesign, stronger pipe, or special installation procedures without any additional cost to the Government.

3.4.2.1 Bottom Preparation

Grade the bottoms of trenches accurately to provide uniform bearing and support for the bottom quadrant of each section of the pipe. Excavate bell holes to the necessary size at each joint or coupling to eliminate point bearing. Remove stones of 3 inch or greater in any dimension, or as recommended by the pipe manufacturer, whichever is smaller, to avoid point bearing.

3.4.2.2 Removal of Unyielding Material

Where unyielding material is encountered in the bottom of the trench, notify the Contracting Officer. Following approval, remove such material 4 inch below the required grade and replaced with suitable materials as provided in paragraph FILLING AND COMPACTION.

3.4.2.3 Removal of Unstable Material

Where unstable material is encountered in the bottom of the trench, remove such material to the depth directed and replace it to the proper grade with suitable material as provided in paragraph FILLING AND COMPACTION. When removal of unstable material is required due to the Contractor's fault or neglect in performing the work, the Contractor is responsible for excavating the resulting material and replacing it without additional cost to the Government.

3.4.2.4 Excavation for Appurtenances

Provide excavation for manholes, catch-basins, inlets, or similar structures sufficient to leave at least 12 inches clear between the outer structure surfaces and the face of the excavation or support members.

3.4.2.5 Gas Distribution

Excavate trenches to a depth that will provide a minimum 18 inches of cover in rock excavation and a minimum 24 inches of cover in other excavation.

3.4.2.6 Water Lines

Excavate trenches to a depth that provides a minimum cover of 2.0 feet from the existing ground surface, or from the indicated finished grade, whichever is lower, to the top of the pipe. For fire protection yard mains or piping, an additional 12 inch of cover is required.

3.4.3 Jacking, Boring, and Tunneling

Unless otherwise indicated, provide excavation by open cut except those sections requested and if, in the opinion of the Contracting Officer, can be safely and properly installed and backfill. Provide a Jacking, Boring, and Tunneling Plan, signed and sealed by a licensed Professional Engineer that includes a work site layout, methods and procedures, equipment, alignment control, monitoring, and contingency for responding to unplanned movements.

3.4.3.1 Pipeline Casing

Provide new smooth wall steel pipeline casing under existing pavement by the boring and jacking method of installation. Provide each new pipeline casing, where indicated and to the lengths and dimensions shown, complete and suitable for use with the new piped utility as indicated.

3.4.3.2 Bore Holes

Mechanically bore holes and case through the soil with a cutting head on a continuous auger mounted inside the casing pipe. Weld lengths of pipe together in accordance with AWS D1.1/D1.1M. Do not use water or other fluids in connection with the boring operation.

3.4.3.3 Cleaning

Clean inside of the pipeline casing of dirt, weld splatters, and other foreign matter which would interfere with insertion of the piped utilities by attaching a pipe cleaning plug to the boring rig and passing it through the pipe.

3.4.3.4 End Seals

After installation of piped utilities in pipeline casing, provide watertight end seals at each end of pipeline casing between pipeline casing and piping utilities. Provide watertight segmented elastomeric end seals.

3.4.4 Underground Utilities

Perform work adjacent to utilities in accordance with procedures outlined by utility owner. Excavation made with power-driven equipment is not permitted within 2 feet of known utility or subsurface construction. For work immediately adjacent to or for excavations exposing a utility or other buried obstruction, excavate by hand. Start hand excavation on each side of the indicated obstruction and continue until the obstruction is uncovered or until clearance for the new grade is assured. Support uncovered lines or other existing work affected by the contract excavation until approval for backfill is granted by the Contracting Officer. Report damage to utility lines or subsurface construction immediately to the Contracting Officer.

3.4.5 Structural Excavation

Make excavations to the lines, grades, and elevations shown, or as directed. Provide trenches and foundation pits of sufficient size to permit the placement and removal of forms for the full length and width of structure footings and foundations as shown. Clean rock or other hard foundation material of loose debris and cut to a firm, level, stepped, or serrated surface. Remove loose disintegrated rock and thin strata.

Concrete placement is not allowed until footing subgrades have been inspected and approved by the Contracting Officer.

3.5 SUBGRADE PREPARATION

3.5.1 General Requirements

Shape subgrade to line, grade, and cross section as indicated. Remove

unsatisfactory and unstable material in surfaces to receive fill or in excavated areas, as determined by proof rolling, and replaced with satisfactory materials or structural fill. Do not place material on surfaces that are muddy, frozen, contain frost, or otherwise containing unstable material. Scarify the surface to a depth of 4 inches prior to placing fill. Step or bench sloped surfaces steeper than 1 vertical to 4 horizontal prior to scarifying. Place 4 inches of loose fill and blend with scarified material. When subgrade is part fill and part excavation or natural ground, scarify to a depth of 8 inches.

3.5.2 Subgrade for Structures, Spread Footings, and Concrete Slabs

Do not excavate below depth shown for structures, spread footings, and concrete slabs. If over excavation occurs, notify the Contracting Officer and remove, replace, and compact as directed. After final rolling, the surface of the subgrade for buildings and pavements must not show deviations greater than 0.05 foot when tested with a 12-foot straightedge applied both parallel and at right angles to the centerline of the area.

3.5.3 Subgrade for Pavements

Compact top 12 inches of subgrade for pavements to at least 95 percent of ASTM D1557. After final rolling, the surface of the subgrade for buildings and pavements must not show deviations greater than 0.05 foot when tested with a 12-foot straightedge applied both parallel and at right angles to the centerline of the area.

3.5.4 Subgrade for Airfield Pavements

Fills composed of soil having a plasticity index (PI) greater than 5 or a liquid limit (LL) greater than 25 will be compacted to not less than 90 percent of ASTM D1557 maximum density. Fills composed of soil having a PI equal to or less than 5 and an LL equal to or less than 25 will be compacted as follows: the top 6 inches will be 100 percent of ASTM D1557 maximum density and the remaining depth of fill will be 95 percent of ASTM D1557 maximum density.

In cut section the top 6 inches of subgrades composed of soil having a PI greater than 5 or an LL greater than 25 will be compacted to not less than 90 percent of ASTM D1557 maximum density. Soils having a PI equal to or less than 5 and an LL equal to or less than 25 will be compacted as follows: the top 6 inches will be 100 percent of ASTM D1557 maximum density and the 18 inches below the top 6 inches will be 95 percent of ASTM D1557 maximum density.

After final rolling, the surface of the subgrade for buildings and pavements must not show deviations greater than 0.05 foot when tested with a 12-foot straightedge applied both parallel and at right angles to the centerline of the area.

3.6 FILLING AND COMPACTION

Prepare ground surface on which backfill is to be placed and provide compaction requirements for backfill materials in conformance with the applicable portions of paragraphs for SUBGRADE PREPARATION. Do not place material on surfaces that are muddy, frozen, or contain frost. Finish compaction by sheepsfoot rollers, pneumatic-tired rollers, steel-wheeled rollers, or other approved equipment well suited to the soil being compacted. Moisten material as necessary to plus or minus 2 percent of

optimum moisture. Fill and backfill to contours, elevations, and dimensions indicated. Compact and test each lift before placing overlaying lift.

3.6.1 Trench Backfill

Backfill trenches to the grade shown. Backfill the trench to 2 feet above the top of pipe prior to performing the required pressure tests. Leave the joints and couplings uncovered during the pressure test.

3.6.1.1 Replacement of Unyielding Material

Replace unyielding material removed from the bottom of the trench with satisfactory material or initial backfill material.

3.6.1.2 Replacement of Unstable Material

Replace unstable material removed from the bottom of the trench or excavation with satisfactory material placed in layers not exceeding 6 inches loose thickness.

3.6.1.3 Bedding and Initial Backfill

Provide bedding of the type and thickness shown. Place initial backfill material and compact it with approved tampers to a height of at least one foot above the utility pipe or conduit. Bring up the backfill evenly on both sides of the pipe for the full length of the pipe. Take care to ensure thorough compaction of the fill under the haunches of the pipe. Except where shown or when specified otherwise in the individual piping section, provide bedding for buried piping in accordance with PART 2 paragraph UTILITY BEDDING MATERIAL. Compact backfill to top of pipe to 85 percent of ASTM D1557. Provide plastic piping with bedding to spring line of pipe.

3.6.1.4 Final Backfill

Do not begin backfill until construction below finish grade has been approved, underground utilities systems have been inspected, tested and approved, forms removed, and the excavation cleaned of trash and debris. Bring backfill to indicated finish grade. Where pipe is coated or wrapped for protection against corrosion, the backfill material up to an elevation 2 feet above sewer lines and one foot above other utility lines need to be free from stones larger than one inch in any dimension. Heavy equipment for spreading and compacting backfill are not to be operated closer to foundation or retaining walls than a distance equal to the height of backfill above the top of footing; compact remaining area in layers not more than 4 inches in compacted thickness with power-driven hand tampers suitable for the material being compacted. Place backfill carefully around pipes or tanks to avoid damage to coatings, wrappings, or tanks. Do not place backfill against foundation walls prior to 7 days after completion of the walls. As far as practicable, bring backfill up evenly on each side of the wall and sloped to drain away from the wall.

Fill the remainder of the trench, except for special materials for buildings and pavements with satisfactory material. Place backfill material and compact as follows:

3.6.1.4.1 Buildings and Pavements

Place backfill up to the required elevation as specified. Do not permit water flooding or jetting methods of compaction. Compact as specified for Structural Fill.

3.6.1.4.2 Turfed or Seeded Areas and Miscellaneous Areas

Deposit backfill in layers of a maximum of 12 inches loose thickness, and compact it to 85 percent maximum density for cohesive soils and 90 percent maximum density for cohesionless soils. Do not permit compaction by water flooding or jetting. Apply this requirement to all other areas not specifically designated above.

3.6.1.5 Heat Distribution System

Free initial backfill material of stones larger than 1/4 inch in any dimension.

3.6.1.6 Electrical Distribution System

Provide a minimum cover of 24 inches from the finished grade to direct burial cable and conduit or duct line, unless otherwise indicated.

3.6.1.7 Displacement of Features

After other required tests have been performed and the trench backfill compacted to 2 feet above the top of the pipe, inspect the pipe to determine whether unexpected or damaging displacement has occurred. Conduct walk-through inspection of pipe sizes larger than 48 inches. Inspect pipes smaller than 48 inches using remote methods using closed circuit television, sonar, or hybrid that can provide a 360-degree inspection of the pipe. Prepare and submit a pipe inspection report consisting of digital video or photos. If, in the judgment of the Contracting Officer, the interior of the pipe shows poor alignment or any other defects that would cause improper functioning of the system, replace or repair the defects as directed at no additional cost to the Government.

3.6.1.8 Buried Tape And Detection Wire

3.6.1.8.1 Buried Warning and Identification Tape

Provide buried utility lines with utility identification tape. Bury tape 12 inches below finished grade; under pavements and slabs, bury tape 6 inches below top of subgrade.

3.6.1.8.2 Buried Detection Wire

Bury detection wire directly above non-metallic piping at a distance not to exceed 12 inches above the top of pipe. Extend the wire continuously and unbroken, from manhole to manhole. Terminate the ends of the wire inside the manholes at each end of the pipe, with a minimum of 3 feet of wire, coiled, remaining accessible in each manhole. Furnish insulated wire over its entire length. Install wires at manholes between the top of the corbel and the frame, and extend up through the chimney seal between the frame and the chimney seal. For force mains, terminate the wire in the valve pit at the pump station end of the pipe.

3.6.2 Structural Fill Placement

Place fill and backfill beneath and adjacent to structures in successive horizontal layers of loose material not more than 8 inches in depth, or in loose layers not more than 4 inches in depth when using hand-operated compaction equipment. Do not place over wet or frozen materials. Compact to at least 90 percent of laboratory maximum density for cohesive materials or 95 percent of laboratory maximum density for cohesionless materials, except as otherwise specified. Perform compaction in such a manner as to prevent wedging action or eccentric loading upon or other damage to the structure. Moisture condition fill and backfill material to within range of plus 2 or minus 2 percent of optimum moisture content at the time of compaction.

3.6.3 Backfill for Appurtenances

After the manhole, catchbasin, inlet, or similar structure has been constructed and the concrete has been allowed to cure for 7 days, place backfill in such a manner that the structure is not be damaged by the shock of falling earth. Deposit the backfill material, compact it as specified for final backfill, and bring up the backfill evenly on all sides of the structure to prevent eccentric loading and excessive stress.

3.6.4 Porous Fill Placement

Provide under floor and area-way slabs on a compacted subgrade. Place in a single lift and compact with a minimum of two passes of a hand-operated plate-type vibratory compactor.

3.6.5 Compaction

3.6.5.1 General Site

Compact underneath areas designated for vegetation and areas outside the 5 foot line of the paved area or structure to 90 percent of ASTM D1557.

3.6.5.2 Adjacent Areas

Compact areas within 5 feet of structures to 95 percent of ASTM D1557.

3.7 FINISHING/FINISH OPERATIONS

During construction, keep embankments and excavations shaped and drained. Maintain ditches and drains along subgrade to drain effectively at all times. Do not disturb the finished subgrade by traffic or other operation. Protect and maintain the finished subgrade in a satisfactory condition until ballast, subbase, base, or pavement is placed. Do not permit the storage or stockpiling of materials on finished subgrade. Do not lay subbase, base course, ballast, or pavement until the subgrade has been checked and approved, and in no case place subbase, base, surfacing, pavement, or ballast on a muddy, spongy, frozen or otherwise unstable subgrade.

Finish the surface of excavations, embankments, and subgrades to a smooth and compact surface in accordance with the lines, grades, and cross sections or elevations shown. Provide the degree of finish for graded areas within 0.1 foot of the grades and elevations indicated except as indicated for subgrades specified in paragraph SUBGRADE PREPARATION. Finish gutters and ditches in a manner that will result in effective

drainage. Finish the surface of areas to be turfed to a smoothness suitable for the application of turfing materials. Repair graded, topsoiled, or backfilled areas prior to acceptance of the work, and re-established grades to the required elevations and slopes.

3.7.1 Capillary Water Barrier

Place a capillary water barrier under concrete floor and area-way slabs grade directly on the subgrade and compact with a minimum of two passes of a hand-operated plate-type vibratory compactor.

3.7.2 Grading Around Structures

Construct areas within 5 feet outside of each building and structure line true-to-grade, shape to drain, and maintain free of trash and debris until final inspection has been completed and the work has been accepted.

3.7.3 Grading

Finish grades as indicated within one-tenth of one foot. Grade areas to drain water away from structures. Maintain areas free of trash and debris. For existing grades that will remain but which were disturbed by Contractor's operations, grade as directed.

3.8 DISPOSITION OF SURPLUS MATERIAL

Remove from Government property all surplus or other soil material not required or not suitable for filling or backfilling, along with brush, refuse, stumps, roots, and timber. Properly disposed of in accordance with all applicable laws and regulations. Prepare plan for Disposition of Surplus Materials to include permissions document to dispose of nonsalable products.

3.9 TESTING

Perform testing as indicated in Table 1. Submit Material Test Reports within 7 days of tests being completed. In addition, submit test data in accordance with Section 01 33 39.10 ADVANCED MODELING (BIM/CIM/GIS/CAD) REQUIREMENTS.

Material Type	Location of Material	Test Method	Test Frequency

Material Type	Location of Material	Test Method	Test Frequency
(1) Undisturbed Native Soil	(1) Structures	Density - ASTM D6938 When ASTM D6938 or ASTM D8167/D8167M is used, check the calibration curves and adjust using only the sand cone method as described in ASTM D1556/D1556M.	(1) One test per 50 linear feet of footing. One test per 500 SF within building line
(2) Fills & Backfills	(2) Structures		(2) One test per 50 linear feet of footing. One test per 500 SF within building line
(3) Subgrades	(3) Airfield		(3) One test per 500 square feet.
(4) Subgrades	(4) Site		(4) One test per 1000 SF
(5) Embankments or Borrow	(5) All		(5) One test per lift per 250 cubic yards
			Double testing frequency for areas compacted by hand-operated machines.
			If ASTM D6938 or ASTM D8167/D8167M is used, check in-place densities by ASTM D1556/D1556M as follows: One check test per lift for every 6 tests.

Material Type	Location of Material	Test Method	Test Frequency
All	All	Moisture Content - ASTM D2216	Two tests per day for each type of fill and backfill. Sample taken immediately prior to compaction after moisture conditioning.
All	All	Moisture Density Relationship - ASTM D1557	One representative test per 500 cubic yards of fill and backfill, or when any change in material occurs which may affect the optimum moisture content or laboratory maximum density. Sample to be taken from stockpile or location of placement.
All	All	Relative Density - ASTM D4253 and ASTM D4254	One test per 2000 square feet, or fraction thereof, of each lift of fill or backfill areas compacted by other than hand-operated machines. Double testing frequency for areas compacted by hand-operated machines.

Material Type	Location of Material	Test Method	Test Frequency
All	All	Gradation - ASTM C136/C136M	One representative test per 500 cubic yards of fill and backfill, or when any change in material occurs which may affect the optimum moisture content or laboratory maximum density. Sample to be taken from stockpile or location of placement.
All	All	Atterberg Limits - ASTM D4318	One representative test per 500 cubic yards of fill and backfill, or when any change in material occurs which may affect the optimum moisture content or laboratory maximum density. Sample to be taken from stockpile or location of placement.
All	All	Organic Content Test - ASTM D2974, Method C	One representative test per 200 lineal feet of embankment.

-- End of Section --

SECTION 31 32 19.13

GEOGRID SOIL STABILIZATION
02/21

PART 1 GENERAL

1.1 SUBMITTALS

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

 Sampling and Testing

 Construction Quality Control (QC) Laboratory

SD-04 Samples

 Seams and Overlaps

SD-06 Test Reports

 Sampling and Testing

1.2 QUALITY ASSURANCE

Provide a construction quality control (QC) laboratory that has also performed quality assurance (QA) testing, if required, of geogrids and geosynthetic drainage layers for at least five completed projects, having a total minimum area of 2 million square feet. Submit qualifications of laboratory carrying current accreditation via the Geosynthetic Accreditation Institute's Laboratory Accreditation Program (GAI-LAP) for the tests it will be required to perform.

1.3 DELIVERY, STORAGE, AND HANDLING

The QC inspector must be present during delivery and unloading of the geosynthetic drainage layer. Ensure the drainage layer material has not been damaged during shipping, storage, or handling. Repair or replace any drainage layer material found to be damaged. Accept delivery of material only after the required submittals have been approved. Label each roll with the manufacturer's name, product identification, lot number, roll number, and roll dimensions. Wrap rolls that have attached geotextiles individually in plastic. Store the rolls in a level and dry area.

PART 2 PRODUCTS

2.1 GEOGRID

Submit one properly identified 24-by-24-inch minimum size geosynthetic drainage layer sample; fasteners proposed for use; and the method of seaming and overlapping. Submit manufacturer's quality control test results. Conform the geogrid to the property requirements listed in Table 1. Where applicable, Table 1 property values represent minimum average

roll values (MARV). The value for AOS represents the maximum average roll value (MaxARV).

Property	Longitudinal	Diagonal	Transverse	General
Rib Pitch (in)	1.6	1.6		
Mid-Rib Depth (in)		0.05	0.05	
Mid-Rib Width (in)		0.04	0.05	
Rib Shape				Rectangular
Aperture Shape				Triangular

2.2 SAMPLING AND TESTING

2.2.1 Manufacturing Quality Control Testing

Provide manufacturing quality control test methods and frequencies in accordance with Table 1 unless otherwise approved. Submit manufacturer's quality control manual and construction quality control test results.

PART 3 EXECUTION

3.1 INSTALLATION

3.1.1 Surface Preparation

Prior to placement of the geosynthetic drainage layer, provide a subgrade that is smooth and free of all materials which could damage the drainage layer.

3.1.2 Placement

Do not damage the geosynthetic drainage layer during placement. Unroll the drainage layer in the direction of maximum slope, keeping the net flat against the subgrade to minimize wrinkles and folds. Do not drag the drainage layer across textured geomembrane if a geotextile is attached to the surface facing the geomembrane. Place adequate ballast (e.g. sandbags) to prevent uplift by wind prior to covering.

3.1.3 Seams and Overlaps

3.1.3.1 Geogrid Seams

Geogrid shall be placed based on manufacturer's recommendations, but in no case should the overlap be less than 1 foot.

3.1.3.2 Geogrid Fasteners

Geogrid rolls shall not typically be mechanically connected except in areas of very soft subgrade. Please follow the manufacturer's recommendations.

3.2 REPAIRS

3.2.1 Geogrid Damage

Make repairs by placing a patch of the geogrid over the damaged area. Extend the patch a minimum of 2 feet beyond the edge of the damage. If more than 25 percent of the roll width is damaged, approval must be obtained to repair or replace the damaged roll.

3.3 PROTECTION AND BACKFILLING

Cover the geogrid with the specified materials within 7 days of acceptance. Place cover soil from the bottom of the slope upward and do not drop directly onto the geogrid from a height greater than 3 feet. Push the cover soil out over the geogrid in an upward tumbling motion so that wrinkles in the geogrid do not fold over. Do not operate equipment on the top surface of the geogrid without permission from the Contracting Officer. Provide an initial loose soil lift thickness of 12 inches. Cover soil compaction and testing requirements are described in Section 31 00 00 EARTHWORK.

-- End of Section --

SECTION 32 01 19.61

SEALING OF JOINTS IN RIGID PAVEMENT

11/19

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM C603	(2014; R 2019) Standard Test Method for Extrusion Rate and Application Life of Elastomeric Sealants
ASTM C639	(2015; R 2020) Standard Test Method for Rheological (Flow) Properties of Elastomeric Sealants
ASTM C661	(2015) Indentation Hardness of Elastomeric-Type Sealants by Means of a Durometer
ASTM C679	(2015; R 2022) Standard Test Method for Tack-Free Time of Elastomeric Sealants
ASTM C719	(2014; R 2019) Standard Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants Under Cyclic Movement (Hockman Cycle)
ASTM C792	(2015; R 2020) Effects of Heat Aging on Weight Loss, Cracking, and Chalking of Elastomeric Sealants
ASTM C793	(2005; R 2017) Standard Test Method for Effects of Laboratory Accelerated Weathering on Elastomeric Joint Sealants
ASTM C920	(2018) Standard Specification for Elastomeric Joint Sealants
ASTM C1016	(2014) Standard Test Method for Determination of Water Absorption of Sealant Backing (Joint Filler) Material
ASTM C1193	(2016) Standard Guide for Use of Joint Sealants
ASTM D412	(2016; R 2021) Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension
ASTM D789	(2015) Determination of Relative Viscosity

and Moisture Content of Polyamide (PA)

ASTM D903	(1998; R 2017) Standard Test Method for Peel or Stripping Strength of Adhesive Bonds
ASTM D5249	(2010; R 2016) Standard Specification for Backer Material for Use with Cold-and Hot-Applied Joint Sealants in Portland-Cement Concrete and Asphalt Joints
ASTM D5893/D5893M	(2016) Standard Specification for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00
SUBMITTAL PROCEDURES:

SD-03 Product Data

Sealants (Factory test reports)

Submit catalog cuts, specifications, Safety Data Sheets and other information documenting conformance to Contract requirements.

Manufacturer's Recommendations

SD-04 Samples

Sealants

For small quantity projects involving less than 10,000 linear feet of joint sealing, the requirement for testing may be waived provided that a Factory Test Report is submitted.

Blocking Media/Backup Materials

Backer Rod

Bond Breaking Tapes

SD-06 Test Reports

Sealants

SD-07 Certificates

Equipment List

SD-08 Manufacturer's Instructions

Sealants

Provide instructions that include, but not limited to: storage

requirements, ambient temperature and humidity ranges, and moisture condition of joints for successful installation; requirements for preparation of joints; safe heating temperature; mixing instructions; installation equipment and procedures; application and disposal requirements; compatibility of sealant with filler material; curing requirements; and restrictions to be adhered to in order to reduce hazards to personnel or to the environment. Submit instructions at least 30 days prior to use.

1.3 QUALITY ASSURANCE

1.3.1 Test Requirements

Test the sealant and backup or separating material for conformance with the referenced material specification. Perform testing of the materials in an approved independent laboratory and submit certified copies of the test reports for approval 30 days prior to the use of the materials at the job site. Submit samples to be retained by the Government for possible future testing if the materials appear defective during or after application. Conformance with the requirements of the laboratory tests specified does not constitute final acceptance of the materials. Base final acceptance on the performance of the in-place materials. Submit samples of the materials (sealant, primer if required, and backup material), in sufficient quantity for testing and approval 30 days prior to the beginning of work. Do not use material until it has been approved.

1.3.2 Trial Joint Sealant Installation

Prior to cleaning and sealing the joints for the entire project, prepare a test section at least 200 ft long using the specified materials and approved equipment, so as to demonstrate the proposed joint preparation and sealing of the types of joints in the project. Following the completion of the test section and before any other joint is sealed, inspect the test section to determine that the materials and installation meet the requirements specified. Inspect joint seal test section. Correct deficiencies and obtain approval of test section prior to installing joint seals. If it is determined that the materials or installation do not meet the requirements, remove the materials, and reclean and reseal the joints at no cost to the Government. Permit the test section meeting the requirements to be incorporated into the permanent work and paid for at the Contract unit price per linear foot for sealing items scheduled. Prepare and seal other joints in the manner approved for sealing the test section. Notify the Contracting Officer upon completion of the test section.

1.4 DELIVERY, STORAGE, AND HANDLING

Inspect materials delivered to the site for visible damage, and unload and store with a minimum of handling. Deliver joint materials in original sealed containers and protect from freezing or overheating. Provide jobsite storage facilities capable of maintaining temperature ranges within manufacturers recommendations.

1.5 ENVIRONMENTAL REQUIREMENTS

Do not proceed with work when weather conditions detrimentally affect the quality of cleaning joints or applying sealants. Proceed with joint preparation and sealing only when weather conditions are in accordance with manufacturer's instructions. Install joint sealant to dry surfaces

and protect sealant and bond breakers from moisture.

1.6 TRAFFIC CONTROL

Do not permit vehicular or heavy equipment traffic on the pavement in the area of the joints being sealed during the protection and curing period of the sealant. Permit traffic on the pavement at the end of the curing period.

PART 2 PRODUCTS

2.1 SEALANTS

Use materials for sealing cracks in accordance with ASTM D5893/D5893M.

Use self-leveling, non-acid curing silicone sealant meeting the following requirements in accordance with ASTM C920 or ASTM C1193:

TEST	TEST METHOD	REQUIREMENTS
Weight Loss	ASTM C792 Modified (see Note 1 below)	10 percent max.
Flow	ASTM C639 (Type I)	Smooth and level
Extrusion Rate	ASTM C603	30 sec. max.
Tack Free Time	ASTM C679	5 hours max.
Hardness (Shore 00) (see Note 2 below)	ASTM C661	30 - 80
Tensile Stress at 150 Percent Elongation (see Note 2 below)	ASTM D412 (Die C)	30 psi max.
Percent Elongation (see Note 2 below)	ASTM D412 (Die C)	700 min.
Accelerated Weathering	ASTM C793	Pass 5000 hours
Bond and Movement Capability	ASTM C719	Pass 10 cycles at plus 50 percent movement (no adhesion or cohesion failure)
Peel	ASTM D903	Minimum 20 psi of width with at least 75 percent cohesive failure

NOTES:
 1. Percent weight loss of wet (uncured) sample after placing in forced-draft oven maintained at 158 degrees plus 1 degree F for two hours.
 2. Specimen cured 21 days at 73 degrees plus 1 degree F and 50 percent plus 5 percent humidity.

ACCELERATED WEATHERING FACTORY TEST REPORT. For the Accelerated Weathering test, in lieu of testing of actual sealant to be used on the project, it is permitted to submit a report of a factory test, performed

within two years of Contract award.

2.2 PRIMERS

Use primers in accordance with the recommendation of the manufacturer.

2.3 BOND BREAKERS

2.3.1 Blocking Media/Backup Materials

Provide backup (joint filler) material that is a compressible, nonshrinking, nonstaining, nonabsorbing, nonreactive material with the sealant. Use backup material compliant with ASTM D5249. Use material with a melting point at least 5 degrees F greater than the pouring temperature of the sealant being used when tested in accordance with ASTM D789. Use material with a water absorption of not more than 5 percent of the sample weight when tested in accordance with ASTM C1016. Use backup (joint filler) material that is 25 plus or minus 5 percent larger in diameter than the nominal width of the crack. Use blocking media consistent with the sealant manufacturer's installation instructions.

2.3.2 Bond Breaking Tapes

Provide a bond breaking tape or separating material that is a flexible, nonshrinkable, nonabsorbing, nonstaining, and nonreacting adhesive-backed tape. Use material with a melting point at least 5 degrees F greater than the pouring temperature of the sealant being used when tested in accordance with ASTM D789. Use bond breaker tape approximately 1/8 in wider than the nominal width of the joint and that does not bond to the sealant. Use bond breaking tape shall be consistent with the sealant manufacturer's installation instructions.

PART 3 EXECUTION

3.1 EXECUTING EQUIPMENT

Submit equipment list and description of the equipment to be used and a statement from the supplier of the sealant that the proposed equipment is acceptable for installing the specified sealant. Use equipment for heating, mixing, and installing seals in accordance with the instructions provided by the sealant manufacturer. Provide equipment, tools, and accessories necessary to clean existing joints and install liquid joint sealants. Maintain machines, tools, and other equipment in proper working condition. Submit a list of proposed equipment to be used in performance of construction work including descriptive data, 30 days prior to use on the project.

3.1.1 Joint Cleaning Equipment

3.1.1.1 Tractor-Mounted Routing and Plowing Tool

Use routing tools for removing old sealant from the joints, of such shape and dimensions and so mounted on the tractor that do not damage the sides of the joints. Use tools designed to be adjusted to remove the old material to varying depths and widths as required. Use equipment capable of maintaining accurate cutting depth and width control. Use a joint plow equipped with a spring or hydraulic mechanism to release pressure on the tool prior to spalling the concrete. Do not permit the use of V-shaped tools or rotary impact routing devices. Permit the use of hand-operated

spindle routing devices to clean and enlarge random cracks.

3.1.1.2 Concrete Saw

Provide a self-propelled power saw, with water-cooled diamond or abrasive saw blades, for cutting joints to the depths and widths specified, for refacing joints, cleaning sawed joints where sandblasting does not provide a clean joint, widening, or deepening existing joints as specified without damaging the sides, bottom, or top edge of joints. Permit single or gang type blades with one or more blades mounted in tandem for fast cutting. Select saw adequately powered and sized to cut specified opening with not more than two passes of the saw through the joint.

3.1.1.3 Sandblasting Equipment

Include with the sandblasting equipment an air compressor, hose, and long-wearing venturi-type nozzle of proper size, shape and opening. Do not permit the maximum nozzle opening to exceed 1/4 in. Use a portable air compressor capable of providing not less than 150 cfm and maintaining a line pressure of not less than 90 psi at the nozzle while in use. Demonstrate compressor capability, under job conditions, before approval. Use a compressor equipped with traps that maintain the compressed air free of oil and water. Use a nozzle with an adjustable guide that holds the nozzle aligned with the joint approximately 1 in above the pavement surface. Adjust the height, angle of inclination and the size of the nozzle to secure satisfactory results.

3.1.1.4 Air Compressor

Use a portable air compressor capable of operating the sandblasting equipment and capable of blowing out sand, water, dust adhering to sidewalls of concrete, and other objectionable materials from the joints. Use a compressor that provides air at a pressure not less than 90 psi and a minimum rate of 150 cubic ft of air per minute at the nozzles and free of oil.

3.1.1.5 Vacuum Sweeper

Use a self-propelled, vacuum pickup sweeper capable of completely removing loose sand, water, joint material, and debris from pavement surface.

3.1.1.6 Hand Tools

Permit the use of hand tools, such as brooms and chisels, when approved, for removing defective sealant from a crack and repairing or cleaning the crack faces.

3.1.2 Sealing Equipment

Use joint sealing equipment of a type required by the sealant manufacturer's installation instructions. Use equipment capable of installing sealant to the depths, widths and tolerances indicated. Do not proceed with joint sealing when malfunctions are noted until the malfunctions are corrected.

3.1.2.1 Cold-Applied, Single-Component Sealing Equipment

Use equipment for installing ASTM D5893/D5893M single component joint sealants that consists of an extrusion pump, air compressor, following

plate, hoses, and nozzle for transferring the sealant from the storage container into the joint opening. Use a nozzle with dimensions that allows the tip of the nozzle to extend into the joint to allow sealing from the bottom of the joint to the top. Maintain the initially approved equipment in good working condition, serviced in accordance with the supplier's instructions, and unaltered in any way without obtaining prior approval. Use lined hoses and seals to prevent moisture penetration and withstand pumping pressures. Use equipment free of contamination from previously used or other type sealant. Permit use of small hand-held air-powered equipment (i.e., caulking guns) for small applications.

3.2 PREPARATION OF JOINTS

Unless otherwise indicated, remove existing material, saw, clean and reseal joints. Do not proceed with final cleaning operations by more than one working day in advance of sealant. Clean joints by removing existing joint sealing compound, bond-breakers, dirt, laitance, curing compound, filler, and protrusions of hardened concrete from the sides and upper edges of the joint space to be sealed and other foreign material with the equipment. Do not permit cleaning procedures that damage joints or previously repaired patches by chipping or spalling. Remove existing sealant to the required depth. Precise shape and size of existing joints vary, and conditions of joint walls and edges vary and include but are not limited to rounding, square edges, sloping, chips, voids, depressions, and projections.

3.2.1 Sawing

3.2.1.1 Facing of Joints

Accomplish facing of joints using a concrete saw as specified in paragraph EQUIPMENT to saw through sawed and filler-type joints to loosen and remove material until the joint is clean and open to the full specified width and depth. Provide exposure of newly clean concrete through removal. Remove burrs and irregularities from sides of joint faces. Stiffen the blade with a sufficient number of dummy (used) blades or washers. Clean, immediately following the sawing operation, the joint opening using a water jet to remove saw cuttings and debris and adjacent concrete surface. Protect adjacent previously cleaned joint spaces from receiving water and debris during the cleaning operation.

- a. Joint Widening (Except Expansion Joints): Saw joints having grooves less than 3/8 in wide and less than 1 in deep to a minimum width and depth, as indicated.

3.2.2 Final Cleaning of Joints

3.2.2.1 Sandblasting

Following removal of existing sealant, and sawing, and immediately before resealing, clean newly exposed concrete joint faces and pavement surface extending to a minimum of 1/2 in up to 2 in from each joint edge by sandblasting until concrete surfaces in the joint space are free of sealants, dust, dirt, water and other foreign materials that prevent bonding of new sealants to the concrete. Use sand particles of the proper size and quality for the work. Perform sandblasting with specified nozzles, air compressor, and other appurtenant equipment. Position nozzles to clean the joint faces. Make at least two passes; one for each joint face. Make as many passes as required for proper cleaning.

Immediately prior to sealing the joint, blow out the joint spaces with compressed air until completely free of sand, water, and dust. Install joint sealants to dry joints. Replace expansion joint filler material damaged in performing the work with new materials of the same type and dimensions as the existing material, or with appropriate blocking media.

3.2.3 Bond Breaker

At the time the joints receive the final cleaning and are dry, install bond breaker material as indicated with a steel wheel or other approved device.

3.2.3.1 Blocking Media (Backer Rod) (Except for Expansion Joints)

When the joint opening is of a greater depth than indicated for the sealant depth, plug or seal off the lower portion of the joint opening using a blocking media/back-up material to prevent the entrance of the sealant below the specified depth. Take care to ensure that the blocking media/backup material is placed at the specified depth and is not stretched or twisted during installation.

3.2.3.2 Bond Breaking Tape

Where inserts or filler materials contain bitumen, or the depth of the joint opening does not allow for the use of a backup material, insert a bond breaker separating tape to prevent incompatibility with the filler materials and three-sided adhesion of the sealant. Bond the tape to the bottom of the joint opening to prevent it from floating up into the new sealant.

3.2.4 Rate of Progress of Joint Preparation

Limit the stages of joint preparation, including sandblasting, air pressure cleaning and placing of the back-up material to only that lineal footage that can be sealed during the same day.

3.2.5 Disposal of Debris

Sweep pavement surface to remove excess joint material, dirt, water, sand, and other debris by vacuum sweepers or hand brooms. Remove the debris immediately to a point off station.

3.3 PREPARATION OF SEALANT

3.3.1 Single-Component, Cold-Applied Sealants

Inspect the ASTM D5893/D5893M sealant and containers prior to use. Reject materials that contain water, hard caking of any separated constituents, nonreversible jell, or materials that are otherwise unsatisfactory. Do not reject sealants that exhibit settlement of constituents in a soft mass that can be readily and uniformly remixed in the field with simple tools.

3.4 INSTALLATION OF SEALANT

3.4.1 Time of Application

After approval of the test section, seal joints immediately following final cleaning and placing of bond breakers. Commence sealing joints when walls are dust free and dry, and when weather conditions meet sealant

manufacturer's instructions. If the above conditions cannot be met, or when rain interrupts sealing operations, reclean and permit the joints to dry prior to installing the sealant.

3.4.2 Sealing Joints

Do not install joint sealant until joints to be sealed have been inspected and approved. Install bond breaker just prior to pouring sealant. Fill the joints with sealant from bottom up until joints are uniformly filled solid from bottom to top using the specified equipment for the type of sealant required. Fill joints to 1/8 in plus or minus 1/16 in below top of pavement, and without formation of voids or entrapped air. Do not permit gravity methods or pouring pots to be used to install the sealant material. Except as otherwise permitted, tool the sealant immediately after application to provide firm contact with the joint walls and to form the indicated sealant profile below the pavement surface. Remove excess sealant that has been inadvertently spilled on the pavement surface. Do not permit traffic over newly sealed pavement until authorized. When a primer is recommended by the manufacturer, apply it evenly to the joint faces in accordance with the manufacturer's recommendations. Check sealed joints frequently to ensure that newly installed sealant is cured to a tack-free condition within the specified time. Protect new sealant from rain during curing period.

3.5 INSPECTION/FIELD QUALITY CONTROL

3.5.1 Joint Cleaning

Inspect joints during the cleaning process to correct improper equipment and cleaning techniques that damage the concrete pavement in any manner. Approve cleaned joints prior to installation of the separating or back-up material and joint sealant.

3.5.2 Sampling Sealant

Obtain a one gal sample of each type of sealant on the project from material used for each 10,000 linear ft or less of joints sealed. Store samples according to sealant manufacturer's instructions. Retain samples until final acceptance of the work.

3.5.3 Sealant Application Equipment

Inspect the application equipment to ensure conformance to temperature requirements, proper proportioning and mixing (if two-component sealant) and proper installation. Suspend operations if there is evidences of bubbling, improper installation, or failure to cure or set until causes of the deficiencies are determined and corrected.

3.5.4 Joint Sealant

Inspect the joint sealant for proper rate of cure and set, bonding to the joint walls, cohesive separation within the sealant, reversion to liquid, entrapped air and voids. Remove sealants exhibiting these deficiencies prior to the final acceptance of the project from the joint, wasted, and replace at no additional cost to the Government. Obtain approval for each joint seal installation.

3.6 ACCEPTANCE

Reject sealer that fails to cure properly, or fails to bond to joint walls, or reverts to the uncured state, or fails in cohesion, or shows excessive air voids, blisters, surface defects, swelling, or other deficiencies, or is not properly recessed within indicated tolerances. Remove rejected sealer and reclean and reseal joints. Perform removal and reseal work promptly by and at the expense of the Contractor.

3.7 CLEAN-UP

Upon completion of the project, remove unused materials from the site and leave the pavement in a clean condition.

-- End of Section --

SECTION 32 11 20

BASE COURSE FOR RIGID PAVING AND SIDEWALK

05/22

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM C117	(2023) Standard Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C131/C131M	(2020) Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C136/C136M	(2019) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM D75/D75M	(2019) Standard Practice for Sampling Aggregates
ASTM D1556/D1556M	(2015; E 2016) Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
ASTM D1557	(2012; E 2015) Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft ³) (2700 kN-m/m ³)
ASTM D2487	(2017; E 2020) Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D3665	(2012; R 2017) Standard Practice for Random Sampling of Construction Materials
ASTM D4318	(2017; E 2018) Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D4718/D4718M	(2015) Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles
ASTM D6938	(2017a) Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow

Depth)

ASTM E11 (2022) Standard Specification for Woven
Wire Test Sieve Cloth and Test Sieves

1.2 DEGREE OF COMPACTION

Degree of compaction required, except as noted in the second sentence, is expressed as a percentage of the maximum laboratory dry density obtained by the test procedure presented in ASTM D1557. Since ASTM D1557 applies only to soils that have 30 percent or less by weight of their particles retained on the 3/4 inch sieve, express the degree of compaction for material having more than 30 percent by weight of their particles retained on the 3/4 inch sieve as a percentage of the laboratory maximum dry density in accordance with ASTM D1557 Method C and corrected with ASTM D4718/D4718M.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Plant, Equipment, and Tools; G

SD-06 Test Reports

Initial Tests; G

In-Place Tests; G

Test Section Report; G

1.4 QUALITY ASSURANCE

Perform sampling and testing using a laboratory approved in accordance with Section 01 45 00 QUALITY CONTROL. Do not start work requiring testing until the testing laboratory has been inspected and approved. All contractor quality control testing laboratories performing acceptance testing require USACE validation by the Material Testing Center (MTC) for both parent laboratory and on-site laboratory. Validation on all laboratories is required to remain current throughout the duration of the paving project. Contact the MTC manager listed at <https://mtc.erdc.dren.mil/requestvalidation.aspx#> for costs and scheduling. Test the materials to establish compliance with the specified requirements and perform testing at the specified frequency. Furnish copies of test results within 24 hours of completion of the tests.

1.4.1 Sampling

Take samples for laboratory testing in conformance with ASTM D75/D75M.

1.4.2 Tests

1.4.2.1 Gradation

Perform gradation in conformance with ASTM C117 and ASTM C136/C136M using sieves conforming to ASTM E11.

1.4.2.2 Liquid Limit and Plasticity Index

Determine liquid limit and plasticity index in accordance with ASTM D4318.

1.4.2.3 Moisture-Density Determinations

Determine the laboratory maximum dry density and optimum moisture in accordance with paragraph DEGREE OF COMPACTION.

1.4.2.4 Field Density Tests

Measure field density in accordance with ASTM D1556/D1556M, or ASTM D6938. For the method presented in ASTM D1556/D1556M, use the base plate, as shown in the drawing. For the method presented in ASTM D6938, check the calibration curves and adjust them, if necessary, using only the sand cone method as described in Annex A2, of the ASTM publication. Use ASTM D6938 to determine the moisture content of the soil. Check the calibration curves furnished with the moisture gauges along with density calibration checks as described in ASTM D6938. Make the calibration checks of both the density and moisture gauges using the prepared containers of material method, as described in Annex A2, in ASTM D6938, on each different type of material to be tested at the beginning of a job and at intervals as directed. Submit calibration curves and related test results prior to using the device or equipment being calibrated.

1.4.2.5 Wear Test

Perform wear tests on rigid pavement and sidewalk base course material in conformance with ASTM C131/C131M.

1.5 ENVIRONMENTAL REQUIREMENTS

Perform construction when the atmospheric temperature is above 35 degrees F. When the temperature falls below 35 degrees F, protect all completed areas by approved methods against detrimental effects of freezing. Correct completed areas damaged by freezing, rainfall, or other weather conditions to meet specified requirements.

1.6 ACCEPTANCE

1.6.1 Tolerances

Acceptance of rigid pavement and sidewalk base course is based on compliance with the tolerances presented in Table 1. Remove and replace any course identified by the failing tests.

TABLE 1	
Measurement	Tolerance

TABLE 1	
Grade	Plus 0, Minus 1/2 inch
Smoothness	Plus/Minus 1/2 inch
Total Thickness	Plus/Minus 1/2 inch
Average Job Thickness	Plus/Minus 1/4 inch
Compaction	
Rigid Pavement and Sidewalk Base Course	Minimum 95 percent

1.6.2 Test Section

Construct a test section consisting of 150 square yards of rigid pavement and sidewalk base course to demonstrate the materials, equipment, and construction processes meet the requirements of this specification. Acceptance of the test section is based on compliance with the tolerances listed in Table 1. Rework, re-compact, or remove and replace test sections that do not meet specification requirements. Do not commence full operations until the test section report has been approved. Use the same equipment, materials, and construction methods for the remainder of construction, unless adjustments are approved in advance.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Rigid Pavement And Sidewalk Base Course

Provide aggregates consisting of crushed stone, gravel, shell, sand, or other sound, durable, approved materials processed and blended or naturally combined. Provide aggregates which are durable and sound, free from lumps and balls of clay, organic matter, objectionable coatings, and other foreign material. Limit the percentage of loss to a maximum of 50 percent after 500 revolutions when tested in accordance with ASTM C131/C131M. Provide aggregates with at least 75 percent by weight retained on each sieve having one freshly fractured face with the area at least equal to 75 percent of the smallest midsectional area of the piece. Provide aggregate that is reasonably uniform in density and quality. Provide aggregates having a maximum size of 2 inches, a minimum of 70 percent passing the 3/4 inch sieve, and within the limits specified as follows:

TABLE 3	
Maximum Allowable Percentage by Weight Passing Square-Mesh Sieve	
Sieve Designation	Rigid Pavement Base Course
No. 10	85

TABLE 3	
No. 200	8

Limit the portion of any blended component and of the completed course passing the No. 40 sieve to be either nonplastic or have a liquid limit not greater than 25 and a plasticity index not greater than 8. Provide any additional stability required to maintain a working platform for construction equipment. If a test section can demonstrate that a material has adequate stability to support construction equipment, the fractured face requirement can be deleted, subject to approval by the Government.

2.2 TESTS, INSPECTIONS, AND VERIFICATIONS

2.2.1 Initial Tests

Perform one of each of the following Initial Tests on the proposed material prior to commencing construction to demonstrate that the proposed material meets all specified requirements prior to installation. Complete this testing for each source if materials from more than one source are proposed.

- a. Gradation.
- b. Liquid limit and plasticity index.
- c. Moisture-density relationship.
- d. Wear.

Submit certified copies of test results for approval not less than 30 days before material is required for the work.

2.2.2 Approval of Material

Tentative approval of material will be based on initial test results.

2.3 EQUIPMENT, TOOLS, AND MACHINES

All plant, equipment, and tools used in the performance of the work are subject to approval by the Government before the work is started. Maintain all plant, equipment, and tools in satisfactory working condition at all times. Submit a list of proposed equipment, including descriptive data. Use equipment capable of minimizing segregation, producing the required compaction, meeting grade controls, thickness control, and smoothness requirements as set forth herein.

PART 3 EXECUTION

3.1 GENERAL REQUIREMENTS

Provide adequate drainage during the entire period of construction to prevent water from collecting or standing on the working area.

3.2 OPERATION OF AGGREGATE SOURCES

Condition aggregate sources on private lands in accordance with local laws and authorities.

3.3 STOCKPILING MATERIAL

Clear and level storage sites prior to stockpiling of material. Stockpile all materials, including approved material available from excavation and grading, in the manner and at the locations designated. Stockpile aggregates on the cleared and leveled areas designated to prevent segregation. Stockpile materials obtained from different sources separately.

3.4 PREPARATION OF UNDERLYING COURSE OR SUBGRADE

Clean the underlying course or subgrade of all foreign substances prior to constructing the rigid pavement and sidewalk base course. Do not construct rigid pavement and sidewalk base course on underlying course or subgrade that is frozen. Construct the surface of the underlying course or subgrade to meet specified compaction and surface tolerances. Correct ruts or soft yielding spots in the underlying courses, areas having inadequate compaction, and deviations of the surface from the specified requirements set forth herein by loosening and removing soft or unsatisfactory material and adding approved material, reshaping to line and grade, and recompacting to specified density requirements. For cohesionless underlying courses or subgrades containing sands or gravels, as defined in ASTM D2487, stabilize the surface prior to placement of the overlying course. Stabilize by mixing the overlying course material into the underlying course and compacting by approved methods. Consider the stabilized material as part of the underlying course and meet all requirements of the underlying course. Do not allow traffic or other operations to disturb the finished underlying course and maintain in a satisfactory condition until the overlying course is placed.

3.5 GRADE CONTROL

Provide a finished and completed rigid pavement and sidewalk base course conforming to the lines, grades, and cross sections shown. Place line and grade stakes as necessary for control.

3.6 MIXING AND PLACING MATERIALS

Mix and place the materials to obtain uniformity of the material at the water content specified. Make such adjustments in mixing or placing procedures or in equipment as directed to obtain the true grades, to minimize segregation and degradation, to reduce or accelerate loss or increase of water, and to provide a satisfactory course.

3.7 LAYER THICKNESS

Compact the completed course to the thickness indicated. Limit individual compacted lifts to a maximum thickness of 6 inches and a minimum thickness of 3 inches. Compact the course(s) to a total thickness that is within the tolerances of paragraph ACCEPTANCE. Where the measured thickness is more than 1/4 inch deficient, correct such areas by scarifying, adding new material of proper gradation, reblading, and recompacting as directed. Where the measured thickness is more than 1/2 inch thicker than indicated, the course will be considered as conforming to the specified thickness requirements. However, the requirements for the overlying course thickness and plan grade are still applicable. The average job thickness will be the average of all thickness measurements taken for the job and within the tolerances of paragraph ACCEPTANCE.

3.8 COMPACTION

Compact each lift of the material, as specified, with approved compaction equipment. For cohesive soils, maintain water content during the compaction procedure to within plus or minus 2 percent of optimum water content determined from laboratory tests as specified in this Section and for cohesionless soils, maintain a water content to facilitate compaction without bulking. Begin rolling at the outside edge of the surface and proceed to the center, overlapping on successive trips at least one-half the width of the roller. Slightly vary the length of alternate trips of the roller. Adjust speed of the roller as needed so that displacement of the aggregate does not occur. Compact mixture with hand-operated power tampers in all places not accessible to the rollers. Continue compaction of the rigid pavement and sidewalk base until each lift is compacted through the full depth to meet the compaction requirements of Table 1. Make such adjustments in compacting or finishing procedures to obtain true grades, to minimize segregation and degradation, to reduce or increase water content, and to ensure a compliant rigid pavement and sidewalk base course. Remove any materials that are found to be non-compliant and replace with compliant material or rework, as directed, to meet the requirements of this specification.

3.9 EDGES OF RIGID PAVEMENT AND SIDEWALK BASE COURSE

Place approved material along the outer edges of the rigid pavement and sidewalk base course in sufficient quantity to compact to the thickness of the course being constructed. When the course is being constructed in two or more lifts, simultaneously roll and compact at least a 2 foot width of this shoulder material with the rolling and compacting of each lift of the rigid pavement and sidewalk base course, as directed.

3.10 FINISHING

Finish the surface of the top lift of rigid pavement base course after final compaction by cutting any overbuild to grade and rolling with a steel-wheeled roller. Do not add thin lifts of material to the top lift of rigid pavement base course to meet grade. If the elevation of the top lift of rigid pavement base course exceeds the tolerances of paragraph ACCEPTANCE, scarify the top lift to a depth of at least 3 inches and blend new material in and compact to bring to grade. Make adjustments to rolling and finishing procedures to minimize segregation and degradation, obtain grades, maintain moisture content, and insure an acceptable rigid pavement base course. If the surface becomes rough, corrugated, uneven in texture, or traffic marked prior to completion, scarify the non-compliant portion and rework and recompact it or replace as directed.

3.11 SMOOTHNESS TEST

Construct the top lift so that the surface shows no deviations exceeding the tolerances of paragraph ACCEPTANCE when tested with a 12 foot straightedge. Test the entire area in both a longitudinal and a transverse direction on parallel lines. Perform the transverse lines 15 feet or less apart, as directed. Perform the longitudinal lines at the centerline of each placement lane and at the 1/8th point in from each side of the lane. Hold the straightedge in contact with the surface and move ahead one-half the length of the straightedge for each successive measurement. Determine the amount of surface irregularity by placing the freestanding (unleveled) straightedge on the surface and measuring the

maximum gap between the straightedge and the surface. Determine measurements along the entire length of the straight edge. Correct deviations exceeding the tolerances of Table 1 by removing material and replacing with new material, or by reworking existing material and compacting it to meet these specifications.

3.12 FIELD QUALITY CONTROL

3.12.1 In-Place Tests

Perform one of each of the following In-Place Tests on samples taken from the placed and compacted rigid pavement and sidewalk base course. Determine sample locations using random sampling in accordance with ASTM D3665. Take samples and test at the rates indicated.

- a. Perform density tests on every lift of material placed and at a frequency of one set of tests for every 250 square yards, or portion thereof, of completed area.
- b. Perform gradation on every lift of material placed and at a frequency of one gradation for every 1,000 square yards, or portion thereof, of material placed.
- c. Perform liquid limit and plasticity index tests at the same frequency as the gradation.
- d. Measure the thickness of each course at intervals providing at least one measurement for each 250 square yards or part thereof. Measure the thickness using test holes, at least 3 inches in diameter through the course.

3.12.2 Approval of Material

Final approval of the materials will be based on tests for gradation, liquid limit, and plasticity index performed on samples taken from the completed and fully compacted course(s).

3.13 TRAFFIC

Completed portions of the rigid pavement base course can be opened to limited traffic, provided there is no marring or distorting of the surface by the traffic. Do not allow heavy equipment on the completed rigid pavement base course except when necessary for construction. When it is necessary for heavy equipment to travel on the completed rigid pavement base course, protect the area against marring or damage to the completed work. Repair damage to meet these specifications.

3.14 MAINTENANCE

Maintain the completed course in a satisfactory condition until the full pavement section is completed and accepted. Immediately repair any defects and repeat repairs as often as necessary to keep the area intact. Retest any course that was not paved over prior to the onset of winter to verify that it still complies with the requirements of this specification. Rework or replace any area that is damaged as necessary to comply with this specification.

3.15 DISPOSAL OF UNSATISFACTORY MATERIALS

Dispose of any unsuitable materials that have been removed outside the limits of Government-controlled land. No additional payments will be made for materials that have to be replaced.

-- End of Section --

SECTION 32 13 14.13

CONCRETE PAVING FOR AIRFIELDS AND OTHER HEAVY DUTY PAVEMENTS

11/22

PART 1 GENERAL

1.1 UNIT PRICES

1.1.1 Measurements

The quantity of concrete to be paid for will be the volume of concrete in cubic yards including thickened edges, where required, placed in the completed and accepted pavement. Concrete will be measured in place in the completed and accepted pavement only within the neat line dimensions shown in the plan and cross section. No deductions will be made for rounded or beveled edges or the space occupied by pavement reinforcement, dowel bars, or electrical conduits, nor for any void, or other structure extending into or through the pavement slab, measuring 3 cubic feet or less in volume. No other allowance for concrete will be made unless placed in specified locations in accordance with the approved contract modification. The quantity of other materials specified herein, and used in the construction of the work covered by this section, will not be measured for payment, but will be considered a subsidiary obligation, covered under the price per cubic yard for concrete. Joint sealing materials are covered in Section 32 01 19.61 SEALING OF JOINTS IN RIGID PAVEMENT.

1.1.2 Payments

1.1.2.1 Lump Sum

The quantity of concrete will be paid for and included in the lump-sum contract price. If less than 100 percent payment is due based on the pay factors stipulated below, a unit price of \$88 per square yard for 8-inch pavement will be used for purposes of calculating the payment reduction. Payment will constitute full compensation for all materials, equipment, plant and tools, and for all labor and other incidentals necessary to complete the concrete pavement, except for other items specified herein for separate payment.

1.1.3 Payment of Lots

When a lot of material fails to meet the specification requirements, that lot will be accepted at a reduced price or be removed and replaced. The lowest computed percent payment determined for any pavement characteristic discussed below (for example, thickness, grade, and surface smoothness) becomes the actual percent payment for that lot. The actual percent payment will be applied to the unit price and the measured quantity of concrete in the lot to determine actual payment. Use results of strength tests to control concreting operations. Strength will be evaluated, but will not be considered for payment adjustment. Remove and replace any subplot not meeting the required 'Concrete Strength for Final Acceptance' at no additional cost to the Government.

1.1.4 Payment Adjustment for Smoothness

1.1.4.1 Straightedge Testing

Record location and deviation from straightedge for all measurements. Determine the computed percent payment for straightedge testing by entering Table 1.

TABLE 1	
PAYMENT ADJUSTMENT FOR SMOOTHNESS USING STRAIGHTEDGE	
Deviation from straightedge for all measurements made within a lot exceed the tolerance specified in paragraph SURFACE SMOOTHNESS by:	Computed Percent Payment
Less than or equal to 5.0 percent	100
More than 5.0 percent but Less than or equal to 10.0 percent, after any reduction of high spots or removal and replacement	95
More than 10.0 percent but Less than or equal to 15.0 percent	90
More than 15.0 percent but Less than or equal to 20.0 percent	75
More than 20.0 percent	Remove and Replace

1.1.4.2 Profilograph Testing

Profilograph testing will not be required.

1.1.5 Payment Adjustment for Plan Grade

Determine the computed percent payment for plan grade by entering TABLE 2.

TABLE 2	
PAYMENT ADJUSTMENT FOR PLAN GRADE	
Percent of all measurements made within a lot are outside the specified tolerance	Computed Percent Payment
Less than or equal to 5.0	100
More than 5.0 but Less than or equal to 10.0	95
More than 10.0 but Less than 20	90

TABLE 2	
PAYMENT ADJUSTMENT FOR PLAN GRADE	
Percent of all measurements made within a lot are outside the specified tolerance	Computed Percent Payment
More than 20.0 but Less than 50	75
50 or more	Remove and Replace

As an example, if 100 measurements are required for the specified lot, and nine of the required measurements are within the Payment Adjustment limits identified in paragraph Plan Grade, 9 percent would be used to determine the computed percent payment of 95 percent.

1.1.6 Payment Adjustment for Thickness

Using the Average Thickness of the lot, determine the computed percent payment for thickness by entering Table 3.

TABLE 3		
PAYMENT ADJUSTMENT FOR THICKNESS		
Deficiency in Thickness Determined by cores inches	Computed Percent Payment	
	Pavements Equal To or Greater Than 8 inches Thick	Pavements Less Than 8 inches Thick
0.00 to 0.24	100	100
0.25 to 0.49	75	65
0.50 to 0.74	50	Remove and Replace
0.75 or greater	Remove and Replace	Remove and Replace

Where either of the two cores from a subplot show a thickness deficiency of 0.75 inch or greater, 0.50 inch for pavements 8 inches or less in thickness, drill two more cores in the subplot and compute the average thickness of the four cores. If this average shows a thickness deficiency of 0.75 inch or more 0.50 inch for pavements 8 inches or less in thickness remove the entire subplot.

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
(AASHTO)

AASHTO M 182 (2005; R 2017) Standard Specification for
Burlap Cloth Made from Jute or Kenaf and
Cotton Mats

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 201.1R (2008) Guide for Conducting a Visual
Inspection of Concrete in Service

ACI 211.1 (1991; R 2009) Standard Practice for
Selecting Proportions for Normal,
Heavyweight and Mass Concrete

ACI 214R (2011) Evaluation of Strength Test Results
of Concrete

ACI 305R (2020) Guide to Hot Weather Concreting

ACI 306R (2016) Guide to Cold Weather Concreting

ACI 325.14R (2017) Guide for Design and Proportioning
of Concrete Mixtures for Pavements

ASTM INTERNATIONAL (ASTM)

ASTM A615/A615M (2022) Standard Specification for Deformed
and Plain Carbon-Steel Bars for Concrete
Reinforcement

ASTM A996/A996M (2016) Standard Specification for
Rail-Steel and Axle-Steel Deformed Bars
for Concrete Reinforcement

ASTM A1064/A1064M (2022) Standard Specification for
Carbon-Steel Wire and Welded Wire
Reinforcement, Plain and Deformed, for
Concrete

ASTM A1078/A1078M (2019) Standard Specification for
Epoxy-Coated Steel Dowels in Concrete
Pavement

ASTM C31/C31M (2024) Standard Practice for Making and
Curing Concrete Test Specimens in the Field

ASTM C33/C33M (2023) Standard Specification for Concrete
Aggregates

ASTM C78/C78M (2022) Standard Test Method for Flexural
Strength of Concrete (Using Simple Beam
with Third-Point Loading)

ASTM C88 (2018) Standard Test Method for Soundness
of Aggregates by Use of Sodium Sulfate or
Magnesium Sulfate

ASTM C94/C94M	(2023) Standard Specification for Ready-Mixed Concrete
ASTM C114	(2022) Standard Test Methods for Chemical Analysis of Hydraulic Cement
ASTM C117	(2023) Standard Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C123/C123M	(2023) Standard Test Method for Lightweight Particles in Aggregate
ASTM C125	(2021a) Standard Terminology Relating to Concrete and Concrete Aggregates
ASTM C131/C131M	(2020) Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C136/C136M	(2019) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C138/C138M	(2023) Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
ASTM C142/C142M	(2017) Standard Test Method for Clay Lumps and Friable Particles in Aggregates
ASTM C143/C143M	(2020) Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C150/C150M	(2022) Standard Specification for Portland Cement
ASTM C172/C172M	(2017) Standard Practice for Sampling Freshly Mixed Concrete
ASTM C174/C174M	(2017) Standard Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores
ASTM C192/C192M	(2019) Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
ASTM C231/C231M	(2024) Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C260/C260M	(2010a; R 2016) Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C294	(2012; R 2017) Standard Descriptive Nomenclature for Constituents of Concrete Aggregates

ASTM C295/C295M	(2019) Standard Guide for Petrographic Examination of Aggregates for Concrete
ASTM C494/C494M	(2019; E 2022) Standard Specification for Chemical Admixtures for Concrete
ASTM C618	(2023; E 2023) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C666/C666M	(2015) Resistance of Concrete to Rapid Freezing and Thawing
ASTM C881/C881M	(2020a) Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete
ASTM C989/C989M	(2024) Standard Specification for Slag Cement for Use in Concrete and Mortars
ASTM C1017/C1017M	(2013; E 2015) Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
ASTM C1064/C1064M	(2017) Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
ASTM C1077	(2017) Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
ASTM C1260	(2023) Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
ASTM C1567	(2023) Standard Test Method for Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
ASTM C1602/C1602M	(2022) Standard Specification for Mixing Water Used in Production of Hydraulic Cement Concrete
ASTM C1646/C1646M	(2016) Making and Curing Test Specimens for Evaluating Frost Resistance of Coarse Aggregate in Air-Entrained Concrete by Rapid Freezing and Thawing
ASTM C1895	(2020) Standard Test Method for Determination of Mohs Scratch Hardness
ASTM D75/D75M	(2019) Standard Practice for Sampling Aggregates
ASTM D1751	(2018) Standard Specification for Preformed Expansion Joint Filler for

Concrete Paving and Structural
Construction (Nonextruding and Resilient
Bituminous Types)

- ASTM D1752 (2018) Standard Specification for
Preformed Sponge Rubber, Cork and Recycled
PVC Expansion Joint Fillers for Concrete
Paving and Structural Construction
- ASTM D2995 (1999; R 2009) Determining Application
Rate of Bituminous Distributors
- ASTM D3665 (2012; R 2017) Standard Practice for
Random Sampling of Construction Materials
- ASTM D4791 (2019) Flat Particles, Elongated
Particles, or Flat and Elongated Particles
in Coarse Aggregate

NATIONAL READY MIXED CONCRETE ASSOCIATION (NRMCA)

- NRMCA QC 3 (2015) Quality Control Manual: Section 3,
Plant Certifications Checklist:
Certification of Ready Mixed Concrete
Production Facilities

U.S. ARMY CORPS OF ENGINEERS (USACE)

- COE CRD-C 55 (1992) Test Method for Within-Batch
Uniformity of Freshly Mixed Concrete
- COE CRD-C 130 (2001) Standard Recommended Practice for
Estimating Scratch Hardness of Coarse
Aggregate Particles
- COE CRD-C 143 (1962) Specifications for Meters for
Automatic Indication of Moisture in Fine
Aggregate
- COE CRD-C 300 (1990) Specifications for Membrane-Forming
Compounds for Curing Concrete
- COE CRD-C 521 (1981) Standard Test Method for Frequency
and Amplitude of Vibrators for Concrete
- COE CRD-C 662 (2009) Determining the Potential
Alkali-Silica Reactivity of Combinations
of Cementitious Materials, Lithium Nitrate
Admixture and Aggregate (Accelerated
Mortar-Bar Method)

U.S. DEPARTMENT OF DEFENSE (DOD)

- TSPWG M 3-250-04.97-05 (2019) Proportioning Concrete Mixtures
with Graded Aggregates for Rigid Airfield
Pavements

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Proposed Techniques; G
Preliminary Proposed Proportioning; G
Pavement Quality Control Plan; G
Stringless Technology; G

SD-03 Product Data

Diamond Grinding Plan; G
Dowels; G
Dowel Bar Assemblies; G
Equipment; G
Concrete Patching Mixture; G

SD-05 Design Data

Proportioning Studies; G

SD-06 Test Reports

Batch Plant Manufacturer's Inspection Report; G
Slipform Paver Manufacturer's Inspection Report; G
Sampling and Testing; G
Diamond Grinding of PCC Surfaces; G
Mixer Performance (Uniformity) Testing; G
Repair Recommendations Plan; G
Paving Lot Report; G
Test Section Paving Lot Report; G
Test Section Lot Report; G

SD-07 Certificates

Contractor Quality Control (CQC) Staff; G
Laboratory Accreditation and Validation; G
NRMCA Certificate of Conformance

Petrographer Resume; G

Licensed Surveyor; G

Concrete Batch Plant Operator; G

1.4 QUALITY CONTROL

1.4.1 Contractor Quality Control (CQC) Staff

Reference Section 01 45 00 QUALITY CONTROL for general CQC personnel qualification requirements. In addition, submit specific CQC personnel qualification requirements listed below. Submit qualifications and resumes for the Concrete Paving CQC Manager and petrographer. Submit certification for all CQC personnel assigned to concrete construction for their respective position:

- a. Identify an individual within the onsite work organization as the Concrete Paving CQC Manager, who is responsible for overall management of concrete paving CQC and has the authority to act in all concrete paving CQC matters including authority to stop concrete paving work which is out of compliance.

The minimum requirements for the Concrete Paving CQC Manager consist of 8 years airfield concrete paving experience similar to work required under this contract with a minimum of 3 years in a concrete paving CQC role. The Concrete Paving CQC Manager is a separate person, and is in addition to the CQC System Manager identified in Section 01 45 00.

- b. CQC personnel responsible for inspection of concrete paving operations: ACI Concrete Transportation Construction Inspector. The ACI Concrete Transportation Construction Inspector is required to be present at the paving site during all paving operations, with the exception of the initial saw cutting operation. The QC manager is required to be present during initial saw cutting operations.
- c. CQC staff is required to oversee all aspects of sawing operations (sawing, flushing, vacuuming, checking for random cracking, lighting).
- d. Lead Foreman or Journeyman of the Concrete Placing, Finishing, and Curing Crews: ACI Advanced Concrete Flatwork Finisher.
- e. Batch Plant Manufacturer's Representative: A technical representative from the batch plant manufacturer is required to be on-site during the test section construction and when a stop is required per Table 16 to inspect and make necessary adjustments to all components of the batch plant including but not limited to aggregate bin weighing operations, water metering, cement and fly ash weighing devices. All necessary inspections and adjustments by the manufacturer technical representative are required to be performed prior to uniformity testing. Submit a written Batch Plant Manufacturer's Inspection Report signed by the technical representative noting all inspection items and corrections and stating the batch plant is capable of producing the volume of concrete as required herein.
- f. Field Testing Technicians: ACI Concrete Field Testing Technician, Grade I.

- g. Slipform Paving Equipment Manufacturer's Representative: A technical representative of the slipform paving equipment manufacturer is required to be on-site during the test section construction to inspect and make corrections to the paving equipment to provide proper operations. Perform a complete and full hydraulic flow test of the vibrator system prior to the test section being placed. Submit a written Slipform Paver Manufacturer's Inspection Report signed by the manufacturer's technical representative noting all inspections, corrections, and flow tests have been performed and the paver is in a condition to perform the required work.
- h. Laboratory Testing Technicians: ACI Concrete Strength Testing Technician and ACI Concrete Laboratory Testing Technician, Level 1 or 2.

1.4.2 Other Staff

Submit for approval the qualifications and resumes for the following staff:

- a. Petrographer: Bachelor of Science degree in geology or petrography, trained in petrographic examination of concrete aggregate according to ASTM C294 and ASTM C295/C295M and trained in identification of the specific deleterious materials and tests identified in this specification. Detail the education, training and experience related to the project-specific test methods and deleterious materials in the Petrographer Resume and submit at least 20 days before petrographic and deleterious materials examination is to commence.
- b. Licensed Surveyor: Perform all survey work under the supervision of a professional land surveyor licensed in the state the work is being performed.
- c. Concrete Batch Plant Operator: National Ready Mix Concrete Association (NRMCA) Plant Manager certification.

1.4.3 Laboratory Accreditation and Validation

Provide laboratory and testing facilities. Submit accreditation of the commercial laboratory by an independent evaluation authority, indicating conformance to ASTM C1077, including all applicable test procedures identified in this specification. If multiple laboratories are proposed, identify which tests will be conducted by each. Submit accreditation documentation a minimum of 30 days before any specified testing is performed. The laboratories performing the tests are required to be accredited in accordance with ASTM C1077, including ASTM C78/C78M and ASTM C1260. Provide current accreditation and include the required and optional test methods, as specified. In addition, all laboratories performing testing require USACE validation by the Material Testing Center (MTC) for both parent laboratory and on-site laboratory. Validation on all laboratories is required to remain current throughout the duration of the paving project. Request MTC laboratory validation at <https://mtc.erdc.dren.mil/requestvalidation.aspx> for costs and scheduling. Contact the MTC Director at <https://mtc.erdc.dren.mil/contact2.aspx> with questions or additional information.

1.4.3.1 Aggregate Testing and Mix Proportioning

Aggregate testing and mixture proportioning studies are required to be

performed by a commercial laboratory.

1.4.3.2 Acceptance Testing

Provide all materials, labor, and facilities required for molding, curing, testing, and protecting test specimens at the paving site and in the laboratory. Provide steel molds for molding the beam specimens. Provide on-site temperature-controlled concrete curing facilities. Provide and maintain boxes or other facilities suitable for storing and curing the specimens at the paving site while in the mold within the temperature range stipulated by ASTM C31/C31M. Provide flexural loading equipment in accordance with ASTM C78/C78M.

1.4.3.3 Contractor Pavement Quality Control Plan

Submit the Pavement Quality Control Plan. The Pavement Quality Control Plan is specific to this specification and supplements the overall Quality Control Plan required by Section 01 45 00 QUALITY CONTROL. Do not produce Portland cement concrete pavement for payment until the pavement quality control plan has been approved. In the pavement quality control plan, address all elements which affect the quality of the pavement including, but not limited to:

- a. Condition of underlying course
- b. Condition of adjacent pavement and dowels
- c. Stockpile management and aggregate grading
- d. Mix proportions and batching operations
- e. Transportation
- f. Placing and consolidation
- g. Placing dowels
- h. Finishing and texturing
- i. Curing
- j. Sawcutting Joints
- k. CQC Testing and Inspection
- l. Inclement / Hot / Cold Weather Plans

1.4.3.4 Laboratory Inspection

The Government will inspect all laboratories requiring validation for equipment and test procedures prior to the start of any concreting operations for conformance to ASTM C1077. Schedule and provide payment for laboratory inspections. Additional payment or a time extension due to failure to acquire the required laboratory validation is not allowed. The laboratory is to maintain this certification for the duration of the project.

1.4.4 Preconstruction Testing of Materials

All sampling and testing is required to be performed using an approved commercial laboratory or, for cementitious materials and chemical admixtures, a laboratory maintained by the manufacturer of the material. Materials are not allowed to be used until notice of acceptance has been given. Additional payment or extension of time due to failure of any material to meet project requirements, or for any additional sampling or testing required is not allowed. Additional tests may be performed by the Government; such Government testing does not relieve any required testing responsibilities.

1.4.4.1 Aggregates

Sample aggregates in the presence of a Government Representative. Obtain samples representative of the materials to be used for the project in accordance with ASTM D75/D75M. Perform all aggregate tests no earlier than 6 months prior to test section construction.

1.4.4.2 Chemical Admixtures, Curing Compounds and Epoxies

At least 30 days before the material is used, submit certified copies of test results for the specific lots or batches to be used on the project. Provide test results less than 5 years old prior to use in the work. Retest chemical admixtures that have been in storage for longer than 6 months or that have been subjected to temperatures outside of manufacturer requirements. Reject if test results do not meet the Level 2 proof of compliance requirements of ASTM C494/C494M.

1.4.4.3 Testing of Cementitious Materials

All materials referenced under paragraph CEMENTITIOUS MATERIALS will be accepted on the basis of manufacturer's certification of compliance, accompanied by mill test reports showing that the material in each shipment meets the requirements of the specification under which it is provided. Provide mill test reports no more than 1 month old, prior to use in the work. Do not use cementitious materials until notice of acceptance has been given. Cementitious materials may be subjected to testing by the Government from samples obtained at the mill, at transfer points, or at the project site. If tests prove that a cementitious material that has been delivered is unsatisfactory, promptly remove it from the project site. Retest cementitious material that has not been used within 6 months after testing, and reject if test results do not meet manufacturer requirements.

1.4.5 Testing During Construction

During construction, sample and test aggregates, cementitious materials, and concrete as specified herein. The Government will sample and test concrete and ingredient materials as considered appropriate. Provide facilities and labor necessary for procurement of representative test samples. Testing by the Government does not relieve the specified testing requirements.

1.4.6 Test Section

1.4.6.1 General

- a. Schedule the test section after all required submittals and uniformity testing has been reviewed and approved. Perform a preparatory meeting before commencing the test section.
- b. Construct a separate test section for each placement method (slipform, fixed form, and hand placement) proposed for use. Construct a separate test section for each paver and each batch plant proposed for use.
- c. Up to 15 days, but not more than 60 days, prior to construction of the concrete pavement, construct a test section as part of the production paving area at an outer edge as indicated on the drawings. Construct the pilot lane and fill-in lane test sections on separate days using the approved mixture proportions. Aggregate proportioning changes may

be required due to specification requirements not being met.

- d. Construct the test section matching the thickest pavement section and underlying structure required in the work. Use the same equipment, materials, and construction techniques on the test sections as proposed for use in all subsequent work. The underlying layers must be reviewed and approved by the Government prior to paving of the test section.
- e. Perform underlying layer preparation, concrete production, placing, consolidating, texturing, curing, construction of joints, and all testing in accordance with applicable provisions of this specification.
- f. Use the test sections to develop and demonstrate the proposed techniques of mixing, hauling, placing, consolidating, finishing, texturing, curing, initial saw cutting, start-up procedures, sampling, testing methods, plant operations, and the preparation of the construction joints for production paving. Report per requirements of paragraph Reports as the Test Section Paving Lot Report.

1.4.6.2 Pilot Lane

Construct the test section consisting of one continuous paving lane at least 400 feet long and to the same thickness as the thickest portion of pavement shown on the Drawings. The test section may not exceed 600 feet; all pavement placed for the test section before or after 400 feet of continuously acceptable placement must be removed. Construct at the same lane width as that required for use in the project. If doweled longitudinal construction joints are required in any of the production pavements, install them full length along one side of the test lane throughout the test section.

1.4.6.3 Fill-In Lane

A fill-in lane is defined as full width concrete placement using two adjacent lanes as forms. Consider the first 400 feet of the initial production fill-in lane as a test section for purposes of testing and evaluation. All requirements for the test section are applicable. Obtain cores from the fill-in lane side of the longitudinal construction joint with the pilot lane. No measurements will be required for longitudinal vertical faces that are against existing or recently placed panels. Straightedge measurements are required across the joint per paragraph Testing Method.

1.4.6.3.1 Alternative Placement Method

If proposed techniques includes alternative placement method resulting in lanes with one free edge and one edge placed against existing or new pavement the first placement will be considered the fill-in lane for test section evaluation purposes. The fill-in lane test section requirements in paragraph Fill-In Lane will apply to the first lane that is not a pilot lane. Test the free edge for all measurements required for a pilot lane and the enclosed edge with all measurements for a fill-in lane.

1.4.6.4 Testing and Inspection

- a. Provide aggregate, fresh concrete, and hardened concrete sampling and testing in accordance with paragraph Testing and Inspection by Contractor and Table 16. Provide inspection of the hardened concrete

for surface smoothness, plan grade, edge slump and joint face deformation in accordance with the specifications. Provide a test section report in accordance with paragraph Reports.

- b. Provide sampling and testing to determine the loss of air content through the paving equipment. Samples are to be obtained before and after the paving equipment along the vibrator path and in-between the vibrators. Obtain one sample of the fresh concrete before the paving equipment has passed with material in the subplot. Once the paver has passed, obtain two samples of the in-place, plastic concrete to the full depth of the placement avoiding the underlying layer. Provide stationing references for all samples. Report this data in the Test Section Lot Report. This testing is in addition to required testing in paragraph TESTING AND INSPECTION FOR CONTRACTOR QUALITY CONTROL DURING CONSTRUCTION and only required during the Test Section(s). Adjustments to air contents to meet the specified air content in paragraph Air Content are only to be made based on measured air contents before the paver has passed. Immediately fill voids resulting from sample collection with freshly mixed concrete, strike off, consolidate with an internal vibrator, and refinish.
- c. No more than three working days after completion of the test sections, procure and evaluate eight cores with a minimum diameter of 6 inches by full depth cut from points selected in the test sections by the Government on a basis of two cores per subplot. Evaluate cores in accordance with paragraph: Evaluation of Cores. Measure cores in accordance with paragraph THICKNESS.

1.4.6.5 Acceptance of Test Section

- a. Construct the test sections meeting the specification requirements including plastic and hardened concrete properties, surface texture, thickness, plan grade, smoothness, joint face deformation, edge slump, and plan joint alignment.

Do not commence production paving until the results on aggregates and concrete, including evaluation of cores, and all pavement measurements for edge slump, joint face deformation, actual plan grade, surface smoothness, and thickness have been submitted and approved, and the payment calculation has been submitted for information only. Remove test sections which do not meet specification requirements and conduct additional test sections, as required. If an acceptable test section is unable to be constructed by slipform paving, repair or replace the slipform paving equipment, or complete the paving using fixed-forms and equipment as required by the specification. Pavement accepted as a production lot will be evaluated and paid as specified in PART 1 GENERAL.

1.4.7 Acceptability of Work

The materials and the pavement itself will be accepted on the basis of production testing. The Government may make check tests to validate the results of the production testing. If the results of the production testing vary by less than 2.0 percent of the Government's test results, the results of the production testing will be used. If the results of the Government and production tests vary by 2.0 percent, but less than 4.0 percent, the average of the two will be considered the value to be used. If these vary by 4.0 percent or more, carefully evaluate each sampling and testing procedure and obtain another series of Government and production

tests on duplicate samples of material. If these vary by 4.0 percent or more, use the results of the tests made by the Government and the Government will continue check testing of this item on a continuous basis until the two sets of tests agree within less than 4.0 percent on a regular basis. Testing performed by the Government does not relieve the specified testing requirements.

1.4.8 Acceptance Requirements

1.4.8.1 Pavement Lots

A lot is that quantity of construction to be evaluated for acceptance with specification requirements. A lot is equal to production paving not to exceed 1000 cubic yards. When the total job does not exceed 1,000 cubic yards, the lot size becomes the total job. In order to evaluate thickness, divide each lot into sublots not to exceed 250 cubic yards. Make grade determinations on the lot as a whole. Make surface smoothness determinations on every 0.1 mile segment in each lot. Select sample locations on a random basis in accordance with ASTM D3665. Areas of pavement placed with hand methods are considered a separate lot for evaluation. When operational conditions cause a lot to be terminated before the specified four sublots have been completed, use the following procedure to adjust the lot size and number of tests for the lot. Where three sublots have been completed, they constitute a lot. Where one or two sublots have been completed, incorporate them into the next lot (except for the last lot), and the total number of sublots used and acceptance criteria adjusted accordingly.

1.4.8.2 Evaluation

Provide all sampling and testing required for acceptance and payment adjustment, including batch tickets with all required acceptance testing. Individuals performing sampling, testing and inspection duties are required to meet the requirements of paragraph: Contractor Quality Control Staff. The Government reserves the right to direct additional samples and tests for any area which appears to deviate from the specification requirements. Testing in these areas is in addition to the subplot or lot testing, and the requirements for these areas are the same as those for a subplot or lot. Provide facilities, and where directed personnel, to assist in obtaining samples for any Government testing.

1.5 DELIVERY, STORAGE, AND HANDLING

1.5.1 Bulk Cementitious Materials

Provide all cementitious materials in bulk at a temperature, as delivered to storage at the site, not exceeding 150 degrees F. Provide sufficient cementitious materials in storage to sustain continuous operation of the concrete mixing plant while the pavement is being placed. Provide separate facilities to prevent any intermixing during unloading, transporting, storing, and handling of each type of cementitious material.

1.5.2 Aggregate Materials

Store aggregate at the site of the batching and mixing plant avoiding breakage, segregation, intermixing or contamination by foreign materials. Store each size of aggregate from each source separately and allow the fine aggregate and the smallest size coarse aggregate to drain. Provide a minimum 24-inch thick sacrificial layer left undisturbed for each

aggregate stored on ground or provide a paved or chemically stabilized surface course beneath the stockpiles. Maintain sufficient aggregate at the site at all times to permit continuous uninterrupted operation of the mixing plant at the time concrete pavement is being placed. Do not allow tracked equipment on coarse aggregate stockpiles.

1.5.3 Other Materials

Store reinforcing bars and accessories above the ground on supports. Store all materials to avoid contamination and deterioration.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

This section is intended to stand alone for construction of concrete pavement. However, where the construction covered herein interfaces with other sections, construct each interface to conform to the requirements of both this section and the other section, including tolerances for both.

2.1.1 SURFACE SMOOTHNESS

Use the straightedge method for testing smoothness. Smoothness requirements do not apply over crowns, drainage structures, or similar penetrations. Maintain detailed notes of the testing results and provide a copy to the Government after each day's testing.

2.1.1.1 Straightedge Testing

Provide the finished surfaces of the pavements with no abrupt change of 1/4 inch or more, and all pavements within the limits specified when checked with an approved 12-foot straightedge. Report measurements to the nearest 1/16 inch. Provide runways and taxiways with a variation from the specified straight edge not greater than 1/8 inch in the longitudinal direction and not greater than 1/4 inch in the transverse direction. Provide all other airfield areas with a variation from a straight edge not greater than 1/4 inch in either the longitudinal or transverse direction.

2.1.1.2 Bumps ("Must Grind" Areas)

Reduce any bumps ("must grind" areas) shown by straightedge measurements which exceed 0.4 inch in height by diamond grinding in accordance with paragraph DIAMOND GRINDING OF PCC SURFACES below until they do not exceed 0.3 inch when retested. Taper such diamond grinding in all directions to provide smooth transitions to areas not requiring diamond grinding.

2.1.1.3 Testing Method

After the concrete has hardened sufficiently to permit walking thereon, but not later than 48 hours after placement, test the entire surface of the pavement in each lot in such a manner as to reveal all surface irregularities exceeding the tolerances specified above. If any pavement areas are diamond ground, retest these areas immediately after diamond grinding. Test the entire area of the pavement in both a longitudinal and a transverse direction on parallel lines. Perform the transverse lines 15 feet or less apart, as directed. Perform the longitudinal lines at the 1/8th point in from each side of the lane and at the centerline of each paving lane shown on the drawings, regardless of whether multiple lanes are allowed to be paved at the same time. Also test other areas having

obvious deviations. Perform longitudinal testing lines continuous across all joints. Perform transverse testing lines for pilot lanes carried to construction joint lines and for fill-in lanes carried 24 inches across construction joints, and the readings in this area applied to the fill-in lane. Perform straightedge testing of the longitudinal edges of slipformed pilot lanes before paving fill-in lanes as specified below.

2.1.1.3.1 Straightedge Testing

Hold the straightedge in contact with the surface and move ahead one-half the length of the straightedge for each successive measurement. Determine the amount of surface irregularity by placing the freestanding (unleveled) straightedge on the pavement surface and measuring the maximum gap between the straightedge and the pavement surface. Determine measurements along the entire length of the straight edge.

2.1.2 Edge Slump and Joint Face Deformation

2.1.2.1 Edge Slump

When slip-form paving is used, provide a maximum of 15.0 percent of each free edge of each pavement panel with a maximum edge slump of 1/4 inch and none of the free edge of the pavement lot with an edge slump exceeding 3/8 inch. (A pavement panel is defined as a lane width by the length between two adjacent transverse contraction joints. The free edge of the pavement is the linear measurement of pavement panel edge originally constructed as non-adjacent to any existing pavement; for example, 100 feet of pilot lane originally constructed as a separate lane, would have 100 feet of free edge on each side; 100 feet of fill-in lane would have no free edge.) The area affected by the downward movement of the concrete along the pavement edge is a maximum of 18 inches back from the edge.

2.1.2.2 Joint Face Deformation

Provide a vertical joint face with a surface within the maximum limits shown in Table 4. Provide the offset measurements from all five Joint Face Deformation Limits from Table 4 at the specified testing frequency. Properly reference all recorded measurements in accordance with paving lane identification and stationing and submit a report within 10 days after measurement is made. Identify areas requiring replacement within the report.

TABLE 4				
JOINT FACE DEFORMATION LIMITS				
Offset from Straightedge Applied Longitudinally to Pavement Surface (a)	Offset from Straightedge Applied Longitudinally to Vertical Face (b)	Offset from Straightedge Applied Top to Bottom Against the Joint Face (c)	Abrupt Offset in Any Direction (d)	Offset of Joint Face from True Vertical (e)
Airfield Pavement				

TABLE 4				
JOINT FACE DEFORMATION LIMITS				
Offset from Straightedge Applied Longitudinally to Pavement Surface (a)	Offset from Straightedge Applied Longitudinally to Vertical Face (b)	Offset from Straightedge Applied Top to Bottom Against the Joint Face (c)	Abrupt Offset in Any Direction (d)	Offset of Joint Face from True Vertical (e)
1/8 inch	1/4 inch	3/8 inch	1/4 inch	1 inch per 12 inches
All Other Pavement				
1/4 inch	All other items same as airfield pavement			
(a) Measurement is taken by placing the straightedge longitudinally on the pavement surface 1 inch from the free edge. Record the longitudinal joint face deformation of the joint on a continuous line 1 inch back from the joint line using the 12-foot straightedge advanced one-half its length for each reading.				
(b) Measurement is taken by applying the straightedge longitudinally along the center of the vertical joint face. Record the longitudinal joint face deformation using the 12-foot straightedge advanced one-half its length for each reading.				
(c) Measurement places a 3/8 inch spacer attached to a straightedge and spaced approximately equal to the thickness of the concrete being measured. The offset from straightedge with spacers is measured by placing the spacers against the top and bottom of the vertical concrete face. Record measurements at 5 foot spacings.				
(d) Check for abrupt offsets at any location that an abrupt change in the joint face plane appears to be present through use of a 12-foot straightedge.				
(e) Measurement of the offset from the joint face to a level in the true vertical position against the joint face. Record measurements at 5 foot spacings.				

2.1.2.3 Edge Slump Determination

Test the pavement surface to determine edge slump immediately after the concrete has hardened sufficiently to permit walking thereon. Perform testing with a minimum 12-foot straightedge to reveal irregularities exceeding the edge slump tolerance specified above. Determine the vertical edge slump at each free edge of each slipformed paving lane constructed. Place the straightedge transverse to the direction of paving and the end of the straightedge located at the edge of the paving lane. Record measurements at 5-to-10 foot spacings, as directed, commencing at the header where paving was started. Initially record measurements at 5 foot intervals in each lane. When no deficiencies are present after 5

measurements, the interval may be increased. The maximum interval is 10 feet. When any deficiencies exist, return the interval to 5 feet. Perform other tests of the exposed joint face to produce a uniform, true vertical joint face. Properly reference all recorded measurements in accordance with paving lane identification and stationing and submit a report within 10 days after measurement is made. Identify areas requiring replacement within the report.

2.1.2.4 Excessive Edge Slump or Joint Face Deformation

When edge slump or joint face deformation exceeding the limits specified above is encountered on either side of the paving lane, record additional straightedge measurements to define the linear limits of the excessive slump or joint face deformation. Remove and replace concrete slabs having excessive edge slump or joint deformation to the next transverse joint in conformance with paragraph REPAIR, REMOVAL AND REPLACEMENT OF NEWLY CONSTRUCTED SLABS. Discontinue use of slip-form paving equipment and procedures that fail to consistently provide edges within the specified tolerances on edge slump and joint face deformation and construct by means of standard paving procedures using fixed forms.

2.1.3 Plan Grade

Within 5 working days after completion of a particular lot, survey the surface of the pavement area for conformance with specified plan grade requirements. The grade will be determined by running lines of levels at intervals corresponding to every longitudinal and transverse joint to determine the elevation at each joint intersection. Resurvey any areas corrected after initial survey.

TABLE 5		
Plan Grade Tolerances		
Airfield Pavements	<u>Finished Surface Measurements at Joint Intersections</u> (after allowable corrections)	
	0-0.04 foot from designed Plan Grade	Acceptable, no Payment Adjustment considered on grade measurements at these Joint Intersections
	0.041 - 0.06 foot from designed Plan Grade	Calculate Plan Grade Pay Adjustment Factor per paragraph Payment Adjustment for Plan Grade
	Greater than 0.06 foot from designed Plan Grade	Remove and Replace affected Panel(s)

TABLE 5		
Heavy-Duty Pavements other than Airfield Pavements	0-0.06 foot from designed Plan Grade	Acceptable, no Payment Adjustment considered on grade measurements at these Joint Intersections
	0.041 foot-0.09 foot from designed Plan Grade	Calculate Plan Grade Pay Adjustment Factor per paragraph Payment Adjustment for Plan Grade
	Greater than 0.09 foot from designed Plan Grade	Remove and Replace affected Panel(s)

The above deviations from the approved grade line and elevation are not permitted in areas where closer conformance with the planned grade and elevation is required for the proper functioning of appurtenant structures. Provide finished surfaces of new abutting pavements that coincide at their juncture. Corrections within the tolerances of paragraph REPAIR, REMOVAL AND REPLACEMENT OF NEWLY CONSTRUCTED SLABS are allowed to improve the payment adjustment or to improve an unacceptable surface to allow for a payment adjustment. Provide horizontal control of the finished surfaces of all airfield pavements that vary not more than 13 mm 1/2 inch from the plan joint alignment indicated.

2.1.3.1 Joint Alignment

Provide survey points for the joint intersections. Provide horizontal control of the finished surfaces of all airfield pavements.

TABLE 6		
Joint Alignment Tolerances		
<u>All Airfield Pavements</u>	<u>Horizontal Measurements of Joint Intersections (both transverse and longitudinal joints)</u>	
	0-1/2 inch from designed Jointing Plan	Acceptable
	Greater than 1/2 inch from the designed Jointing Plan	Remove and Replace affected Panel(s)

2.1.4 Flexural Strength

Each lot of pavement will be evaluated for acceptance for flexural strength in accordance with paragraph Sampling and Testing and paragraph Computations.

2.1.4.1 Sampling and Testing

For acceptance, obtain one composite sample of concrete from each subplot in accordance with ASTM C172/C172M from one batch or truckload. Fabricate and cure test beams 6 x 6 inches in accordance with ASTM C31/C31M; and test at 14 days in accordance with ASTM C78/C78M. Test two beams per subplot (8 per lot).

2.1.4.2 Computations

Average the eight 14-day strength tests for the lot. Use the average strength in accordance with paragraph Concrete Strength For Final Acceptance.

2.1.5 Thickness

Each lot of pavement will be evaluated for acceptance and payment adjustment in accordance with the following procedure. Drill two cores, between 4 and 6 inches in diameter, from the pavement, per subplot (8 per lot). Drill the cores within 3 days after lot placement, fill the core holes with an approved concrete patching mixture, and respray the cored areas with curing compound. Prevent the core hole from drying or damage until backfilled. Complete backfilling of core hole during the subsequent production placement or within 5 calendar days, whichever occurs first. Record eight measurements of thickness around the circumference of each core and one in the center, in accordance with ASTM C174/C174M. Provide the results with the thickness measurement data. Average the pavement thickness from the 8 cores for the lot and evaluate as described in paragraph Payment Adjustment For Thickness above.

2.1.6 Evaluation of Cores

Record and submit testing, inspection, and evaluation of each core for mortar-rich surface, uniformity of aggregate distribution, segregation, voids, cracks, and depth of reinforcement or dowels (if present). Moisten the core with water to visibly expose the aggregate and take a minimum of three photographs of the sides of the core's entire length, rotating the core approximately 120 degrees between photographs. Provide photographs with the clarity and quality to identify the defects identified above. Each core is to be identified on the top with the core number referenced to paving lot plan view. Photograph the core against a contrasting background, in profile, and with an extended tape measure parallel and to the right of the core with incremental measurements clearly visible. Provide plan view of location for each core. Store the cores and make available to the Government when requested, until otherwise directed.

2.1.7 Diamond Grinding of PCC Surfaces

Those performing diamond grinding are required to have a minimum of three years' experience in diamond grinding of airfield pavements. In areas not meeting the specified limits for surface smoothness and plan grade, reduce high areas to attain the required smoothness and grade, except as depth and surface area is limited below. Reduce high areas by diamond grinding the hardened concrete with approved equipment after the concrete is at a minimum age of 14 days. Perform diamond grinding by sawing with an industrial diamond abrasive which is impregnated in the saw blades. Assemble the saw blades in a cutting head mounted on a machine designed specifically for diamond grinding that produces the required texture and smoothness level without damage to the concrete pavement or joint faces.

Utilize diamond grinding equipment with saw blades that are 1/8-inch wide, a minimum of 55 to 60 blades per 12 inches of cutting head width, and cut a path with a minimum width of 3 ft. Diamond grinding equipment that causes ravels, aggregate fractures, spalls or disturbance to the joints is not permitted. The maximum area corrected by diamond grinding the surface of the hardened concrete is 10 percent of the total area of any subplot. The maximum depth of diamond grinding is 1/4 inch. Provide diamond grinding machine equipped to flush and vacuum the pavement surface. Dispose of all debris from diamond grinding operations off Government property. Prior to diamond grinding, submit a Diamond Grinding Plan for review and approval. At a minimum, include the daily reports for the deficient areas, the location and extent of deficiencies, corrective actions, and equipment. Remove and replace all pavement areas requiring plan grade or surface smoothness corrections in excess of the limits specified above in conformance with paragraph REPAIR, REMOVAL AND REPLACEMENT OF NEWLY CONSTRUCTED SLABS. Repair aggregate popouts using the core and patch method of paragraph REPAIRING SPALLS ALONG JOINTS. All areas in which diamond grinding has been performed are subject to the thickness tolerances specified in paragraph Thickness, above.

Prior to production diamond grinding operations, perform a test section at the approved location. Perform a test section that consists of a minimum of two adjacent passes with a minimum length of 40 feet to allow evaluation of the finish, transition between adjacent passes, and the results of crossing a transverse joint. Production diamond grinding operations are not to be performed prior to approval.

2.2 CEMENTITIOUS MATERIALS

Provide cementitious materials consisting of Portland cement, blended cement or Portland cement in combination with supplementary cementitious materials (SCM), that conform to appropriate specifications listed below. New submittals are required when the cementitious materials sources or types change.

2.2.1 Portland Cement

Provide Portland cement conforming to ASTM C150/C150M, Type I.

2.2.2 Blended Cements

Provide blended cement conforming to ASTM C595/C595M, Type IP, IS, or IL. Provide pozzolan added to the Type IP blend consisting of ASTM C618 Class F or Class N and that is interground with the cement clinker. Include a written statement from the manufacturer that the amount of pozzolan in the finished cement does not vary more than plus or minus 5 mass percent of the finished cement from lot to lot or within a lot. Provide limestone added to the Type IL blend that is interground with the cement clinker. Include a written statement from the manufacturer that the amount of limestone in the finished cement does not vary more than plus or minus 2.5 mass percent of the finished cement from lot to lot or within a lot. Limit the percent of slag, pozzolan, or limestone to a maximum of IS(50), IP(35) or IL(15). The percentage and type of mineral admixture used in the blend is not allowed to change from that submitted for the aggregate evaluation and mixture proportioning.

2.2.3 Pozzolan

2.2.3.1 Fly Ash

Provide fly ash that conforms to ASTM C618, Class F, including the optional requirement for uniformity with a loss on ignition not exceeding 3 percent. Provide Class F fly ash for use in mitigating Alkali-Silica Reactivity with a total equivalent alkali content less than 4 percent.

2.2.3.2 Raw or Calcined Natural Pozzolan

Provide natural pozzolan that is raw or calcined and conforms to ASTM C618, Class N, including the optional requirement for uniformity with a loss on ignition not exceeding 3 percent. Provide Class N pozzolan for use in mitigating Alkali-Silica Reactivity with a total equivalent alkali content less than 4 percent.

2.2.3.3 Ultra Fine Fly Ash and Ultra Fine Pozzolan

Provide Ultra Fine Fly Ash (UFFA) and Ultra Fine Pozzolan (UFP) that conforms to ASTM C618, Class F or N, and the following additional requirements:

- a. The strength activity index at 28 days of age of at least 95 percent of the control specimens.
- b. The average particle size is a maximum of 6 microns.

2.2.4 Slag Cement

Provide slag cement (ground-granulated blast-furnace slag) that conforms to ASTM C989/C989M, Grade 100 or Grade 120.

2.2.5 Supplementary Cementitious Materials (SCM) Content

Use of one of the SCMs listed below is optional, unless the SCM is required to mitigate ASR. The use of SCMs is encouraged in accordance with Section 01 33 29 SUSTAINABILITY REQUIREMENTS AND REPORTING.

TABLE 7		
SUPPLEMENTARY CEMENTITIOUS MATERIALS CONTENT		
Supplementary Cementitious Material	Minimum Content (percent)	Maximum Content (percent)
Class N Pozzolan and Class F Fly Ash		
SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃ > 70 percent	25	35
SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃ > 80 percent	20	35
SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃ > 90 percent	15	35
UFFA and UFP	7	16
Slag Cement	40	50

2.3 AGGREGATES

Provide aggregates meeting the requirements of this specification. If aggregate sources in the project area do not meet the requirements of this specification, provide aggregates from sources outside the project area.

2.3.1 Aggregate Sources

2.3.1.1 Durability of Coarse Aggregate

Provide aggregate with a satisfactory service record in freezing and thawing of at least 5 years successful service in three concrete paving projects. Include a condition survey of the existing concrete and a review of the concrete-making materials, including coarse aggregates, cement, and mineral admixtures in the service record. Consider the previous aggregate source and test results, cement mill certificate data, mineral admixture chemical and physical composition, and the mix design (cement factor and water-cementitious material ratio) in the review. Provide service record performed by an independent third-party professional engineer, petrographer, or concrete materials engineer along with their resume. Include photographs and a written report addressing D-cracks and popouts in accordance with ACI 201.1R in the service record. Provide coarse aggregate with a durability factor of 80 or more when subjected to freezing and thawing of specimens prepared in accordance with ASTM C1646/C1646M and tested in accordance with ASTM C666/C666M, Procedure A, when a coarse aggregate size group or source proposed for use does not have a satisfactory demonstrable service record. Test all coarse aggregate size groups and sources proposed for use individually.

2.3.1.2 Alkali-Silica Reactivity

Evaluate and test fine and coarse aggregates to be used in all concrete for alkali-aggregate reactivity. Test all size groups and sources proposed for use individually.

- a. Evaluate the aggregate size groups and sources separately using ASTM C1260. Reject individual aggregates with test results that indicate an expansion of greater than 0.08 percent after 28 days of immersion in 1N NaOH solution, or perform additional testing as follows: utilize the proposed Portland cement, blended cement, and SCM, or Lithium Nitrate in combination with each individual aggregate. If only SCMs are being evaluated, test in accordance with ASTM C1567. If Lithium Nitrate is being evaluated, with or without SCMs, test in accordance with COE CRD-C 662. Determine the quantity that meets all the requirements of these specifications and that lowers the expansion equal to or less than 0.08 percent after 28 days of immersion in a 1N NaOH solution. Base the mixture proportioning on the highest percentage of SCM required to mitigate ASR-reactivity.
- b. If any of the above options does not lower the expansion to less than 0.08 percent after 28 days of immersion in a 1N NaOH solution, reject the aggregate(s) and submit new aggregate sources for retesting. Submit the results of testing for evaluation and acceptance.

2.3.1.3 Combined Aggregate Gradation

In addition to the grading requirements specified for coarse aggregate and for fine aggregate, provide the combined aggregate grading meeting the following requirements:

- a. Provide materials selected and the proportions used such that when the Coarseness Factor (CF) and the Workability Factor (WF) are plotted on a diagram as described in d. below, the point and its associated production tolerance thus determined falls within the parallelogram described therein. Refer to TSPWG M 3-250-04.97-05 for combined aggregate plot locations for the intended placement technique(s).
- b. Determine the Coarseness Factor (CF) from the following equation:
$$CF = \frac{(\text{cumulative percent retained on the } 3/8 \text{ inch sieve})(100)}{(\text{cumulative percent retained on the No. 8 sieve})}$$
- c. The Workability Factor (WF) is defined as the percent passing the No. 8 sieve based on the combined aggregate gradation. Adjust the WF, prorated upwards only, by 2.5 percentage points for each 94 pounds per cubic yard of cementitious material greater than 564 pounds per cubic yard.
- d. Plot a diagram using a rectangular scale with WF on the Y-axis with units from 20 (bottom) to 45 (top), and with CF on the X-axis with units from 80 (left side) to 30 (right side). On this diagram, plot a parallelogram with corners at the following coordinates (CF-75, WF-28), (CF-75, WF-40), (CF-45, WF-32.5), and (CF-45, WF-44.5). If the point determined by the intersection of the computed CF and WF does not fall within the above parallelogram, revise the grading of each size of aggregate used and the proportions selected as necessary.
- e. Plot the associated production tolerance limits, identified in Table 16, around the CF and adjusted WF point.

2.3.2 Coarse Aggregate

2.3.2.1 Coarse Aggregate Composition

Provide coarse aggregate consisting of crushed or uncrushed gravel, crushed stone, or a combination thereof. Provide aggregates, as delivered to the mixers, consisting of clean, hard, uncoated particles meeting the requirements of ASTM C33/C33M except as specified herein. Provide coarse aggregate with no more than 40 percent loss when subjected to the Los Angeles abrasion test in accordance with ASTM C131/C131M. Provide coarse aggregates with a maximum sodium sulfate soundness loss of 12 percent, or with a magnesium sulfate soundness loss of 18 percent after five cycles when tested in accordance with ASTM C88.

2.3.2.2 Particle Shape Characteristics

Provide particles of the coarse aggregate that are generally spherical or cubical in shape. The quantity of flat particles and elongated particles in any size group coarser than the 3/8 inch sieve are not allowed to exceed 20 percent by weight as determined by the Flat Particle Test and the Elongated Particle Test of ASTM D4791, Method A. A flat particle is defined as one having a ratio of width to thickness greater than 3; an elongated particle is one having a ratio of length to width greater than 3.

2.3.2.3 Size and Grading

Provide coarse aggregate with a nominal maximum size (as defined in ASTM C125) of 1.5 inches with a minimum of 10 percent retained on the 1.0 inch sieve of the proposed combined aggregate gradation that meets the

criteria of paragraph COMBINED AGGREGATE GRADATION. Grade and provide the coarse aggregates in a minimum of two size groups meeting the individual grading requirements of ASTM C33/C33M, Size No. 4 (1.5 inches to 0.75 inch) and Size No. 67 (0.75 inch to No. 4). A third coarse aggregate size group may be required to meet the criteria of paragraph Combined Aggregate Gradation.

Mix designs that include a minimum of three coarse aggregate size groups can use grading limits not defined by ASTM C33/C33M provided all other requirements are met. Provide upper and lower grading limits of historic gradations and for all proposed coarse aggregates not defined by ASTM C33/C33M but intended for use in the mix design.

2.3.2.4 Deleterious Materials - Airfield Pavements

The amount of deleterious material in each individual size group and source of coarse aggregate is not allowed to exceed the limits shown in Table 8A below, determined in accordance with the test methods shown.

TABLE 8A		
LIMITS OF DELETERIOUS MATERIALS IN COARSE AGGREGATE FOR AIRFIELD PAVEMENTS		
Percentage by Mass		
Materials (h)	Severe Weather	Moderate Weather
Clay lumps and friable particles (ASTM C142/C142M)	0.2	0.2
Shale (a) (ASTM C295/C295M)	0.1	0.2
Material finer than No. 200 sieve (b) (ASTM C117)	0.5	0.5
Lightweight particles (c) (ASTM C123/C123M)	0.2	0.2
Clay ironstone (d) (ASTM C295/C295M)	0.1	0.5
Chert, cherty stone, and other aggregates (less than 2.40 Sp. Gr.) (e) (ASTM C123/C123M and ASTM C295/C295M)	0.1	0.5
Claystone, mudstone, and siltstone (f) (ASTM C295/C295M)	0.1	0.1
Shaly and argillaceous limestone (g) (ASTM C295/C295M)	0.2	0.2
Other soft particles (COE CRD-C 130)	1.0	1.0
Total of all deleterious substances exclusive of material finer than No. 200 sieve	1.0	2.0

TABLE 8A		
LIMITS OF DELETERIOUS MATERIALS IN COARSE AGGREGATE FOR AIRFIELD PAVEMENTS		
Percentage by Mass		
Materials (h)	Severe Weather	Moderate Weather
(a) Shale is defined as a fine-grained, thinly laminated or fissile sedimentary rock. It is commonly composed of clay or silt or both. It has been indurated by compaction or by cementation, but not so much as to have become slate.		
(b) Limit for material finer than No. 200 sieve is allowed to be increased to 1.5 percent for crushed aggregates if the fine material consists of crusher dust that is essentially free from clay or shale. Use XRD or other appropriate techniques as determined by petrographer to quantify amount and justify increase.		
(c) Test with a separation medium with a density of Sp. Gr. of 2.0. This limit does not apply to coarse aggregate manufactured from blast-furnace slag unless contamination is evident.		
(d) Clay ironstone is defined as an impure variety of iron carbonate, iron oxide, hydrous iron oxide, or combinations thereof, commonly mixed with clay, silt, or sand. It commonly occurs as dull, earthy particles, homogeneous concretionary masses, or hard-shell particles with soft interiors. Other names commonly used for clay ironstone are "chocolate bars" and limonite concretions.		
(e) Chert is defined as a rock composed of quartz, chalcedony or opal, or any mixture of these forms of silica. It is variable in color. The texture is so fine that the individual mineral grains are too small to be distinguished by the unaided eye. Its hardness is such that it scratches glass but is not scratched by a knife blade. It may contain impurities such as clay, carbonates, iron oxides, and other minerals. Cherty stone is defined as any type of rock (generally limestone) that contains chert as lenses and nodules, or irregular masses partially or completely replacing the original stone. Other aggregates consist of obsidian, ash tuff, and palygorskite.		
(f) Claystone, mudstone, or siltstone, is defined as a massive fine-grained sedimentary rock that consists predominantly of indurated clay or silt without laminations or fissility. It may be indurated either by compaction or by cementation.		
(g) Shaly limestone is defined as limestone in which shale occurs as one or more thin beds or laminae. These laminae may be regular or very irregular and may be spaced from a few inches down to minute fractions of an inch. Argillaceous limestone is defined as a limestone in which clay minerals occur disseminated in the stone in the amount of 10 to 50 percent by weight of the rock; when these make up from 50 to 90 percent, the rock is known as calcareous (or dolomitic) shale (or claystone, mudstone, or siltstone).		

TABLE 8A		
LIMITS OF DELETERIOUS MATERIALS IN COARSE AGGREGATE FOR AIRFIELD PAVEMENTS		
Percentage by Mass		
Materials (h)	Severe Weather	Moderate Weather
(h) Perform testing in accordance with the referenced test methods, except use the minimum sample size specified below.		

2.3.2.5 Testing Sequence for Deleterious Materials in Coarse Aggregate - Airfields Only

No extension of time or additional payment due to any delays caused by the testing, evaluation, or personnel requirements is allowed. The minimum test sample size of the coarse aggregate is 200 pounds for the 3/4 inch and larger maximum size and 25 pounds for the No. 4 to 3/4 inch coarse aggregate. Provide facilities for the ready procurement of representative test samples. The testing procedure on each sample of coarse aggregate for compliance with limits on deleterious materials is as follows:

Step 1: Wash each full sample of coarse aggregate for material finer than the No. 200 sieve. Discard material finer than the No. 200 sieve.

Step 2: Test remaining full sample for clay lumps and friable particles and remove.

Step 3. Test remaining full sample for chert and cherty stone with SSD density of less than 2.40 specific gravity. Remove lightweight chert and cherty stone. Retain other materials less than 2.40 specific gravity for Step 4.

Step 4: Test the materials less than 2.40 specific gravity from Step 3 for lightweight particles (Sp. GR. 2.0) and remove. Restore other materials less than 2.40 specific gravity to the sample.

Step 5: Test remaining sample for clay-ironstone, shale, claystone, mudstone, siltstone, shaly and argillaceous limestone, and remove.

Step 6: Test a minimum of one-fifth of remaining full sample for other soft particles.

2.3.2.6 Deleterious Material - Heavy Duty Pavements

The amount of deleterious material in each size group of coarse aggregate is not to exceed the limits in Table 8B when tested as indicated.

TABLE 8B	
LIMITS OF DELETERIOUS MATERIALS IN COARSE AGGREGATE FOR HEAVY DUTY PAVEMENTS	
Percentage by Mass	
Clay lumps and friable particles (ASTM C142/C142M)	2.0
Material finer than No. 200 sieve (ASTM C117)	1.0
Lightweight particles (ASTM C123/C123M)	1.0
Other soft particles (COE CRD-C 130)	2.0
Total of all deleterious substances, exclusive of material finer than No. 200 sieve	5.0

The limit for material finer than the No. 200 sieve is allowed to be increased to 1.5 percent for crushed aggregates consisting of crusher dust that is essentially free from clay or shale. Use a separation medium for lightweight particles with a density of 2.0 specific gravity. This limit does not apply to coarse aggregate manufactured from blast-furnace slag unless contamination is evident.

2.3.3 Fine Aggregate

2.3.3.1 Fine Aggregate Composition

Provide fine aggregate consisting of natural sand, manufactured sand, or a combination of the two, each composed of clean, hard, durable particles meeting the requirements of ASTM C33/C33M. Stockpile and batch each type of fine aggregate separately. Provide fine aggregate with particles that are generally spherical or cubical in shape. For fine aggregate provided as a combination of sources, test each source individually.

2.3.3.2 Grading

Provide fine aggregate, as delivered to the mixer, with a grading that conforms to the requirements of ASTM C33/C33M and having a fineness modulus of not less than 2.50 nor more than 3.40. For fine aggregate supplied as a combination of sources, determine the fineness modulus on a composite sample.

2.3.3.3 Deleterious Material

The minimum test sample size for fine aggregate proposed for use in airfield paving is 10 pounds. The amount of deleterious material in the fine aggregate is not to exceed the limits listed in Table 8 when performed on the full sample:

TABLE 8	
LIMITS OF DELETERIOUS MATERIALS IN FINE AGGREGATE	
Material	Percentage by Mass
Clay lumps and friable particles ASTM C142/C142M	1.0
Material finer than No. 200 sieve ASTM C117	3.0
Lightweight particles ASTM C123/C123M using a medium with a density of Sp. Gr. of 2.0	0.5
Total of all above	3.0

2.3.3.4 Testing Sequence for Deleterious Materials in Fine Aggregate - Airfields Only

The testing procedure on each sample of fine aggregate for compliance with limits on deleterious materials is as follows:

Step 1: Wash each full sample of fine aggregate for material finer than the No. 200 sieve. Discard material finer than the No. 200 sieve.

Step 2: Test remaining full sample for clay lumps and friable particles and remove.

Step 3. Test remaining full sample for lightweight particles (Sp. GR. 2.0).

2.4 CHEMICAL ADMIXTURES

2.4.1 General Requirements

Only use chemical admixtures when the specific admixture type and manufacturer is the same material used in the mixture proportioning studies. Provide all chemical admixtures from the same manufacturer. Provide air-entraining admixture conforming to ASTM C260/C260M. Use an accelerating admixture conforming to ASTM C494/C494M, Type C or Type E, when specified in paragraph MIXTURE PROPORTIONS below provided it is not used to reduce the amount of cementitious material. Calcium chloride and admixtures containing calcium chloride are not allowed. Provide retarding or water-reducing admixture that meet the requirements of ASTM C494/C494M, Type A, B, or D, except that the 6-month and 1-year compressive strength tests are waived. ASTM C494/C494M, Type F and G high range water reducing admixtures and Type S specific performance admixtures are not allowed. ASTM C1017/C1017M flowable admixtures are not allowed.

2.5 MEMBRANE FORMING CURING COMPOUND

Provide membrane forming curing compound that conforms to COE CRD-C 300 and is white pigmented.

2.6 WATER

Provide water for mixing and curing that is fresh, clean, potable, and free of injurious amounts of oil, acid, salt, or alkali, except that

non-potable water, or water from concrete production operations, can be used if it meets the requirements of ASTM C1602/C1602M.

2.7 JOINT MATERIALS

2.7.1 Expansion Joint Material

Provide preformed expansion joint filler material conforming to ASTM D1751 or ASTM D1752 Type II or III that is compatible with the sealant utilized.

Provide expansion joint filler that is 3/4 inch thick, unless otherwise indicated, and provided in a single full depth piece.

2.7.2 Slip Joint Material

Provide slip joint material that is 1/4 inch thick expansion joint filler, unless otherwise indicated, conforming to paragraph EXPANSION JOINT MATERIAL.

2.8 REINFORCING

Provide reinforcement that is free from loose, flaky rust, loose scale, oil, grease, mud, or other coatings that might reduce the bond with concrete. Removal of thin powdery rust and tight rust is not required. However, reinforcing steel which is rusted to the extent that it does not conform to the required dimensions or mechanical properties is not allowed to be used.

2.8.1 Welded Wire Reinforcement

Provide welded wire reinforcement that is deformed or smooth, conforming to ASTM A1064/A1064M, and provided in flat sheets.

2.9 DOWELS

2.9.1 Dowels

Provide dowels in single piece bars fabricated or cut to length at the shop or mill before delivery to the site. Dowels are to be free of loose, flaky rust and loose scale and be clean and straight. Dowels may be sheared to length provided that the deformation from true shape caused by shearing does not exceed 0.04 inch on the diameter of the dowel and does not extend more than 0.04 inch from the end of the dowel. Dowels are required to be smooth steel bars conforming to ASTM A615/A615M, Grade 40 or 60; ASTM A996/A996M, Grade 50 or 60. Epoxy coat dowels in conformance with Type 1 coating requirements of ASTM A1078/A1078M, to include the ends. Provide grout retention rings that are fully circular metal or plastic devices capable of supporting the dowel until the epoxy hardens. Dowel sleeves or inserts are not permitted.

2.9.2 Dowel Bar Assemblies

Provide dowel bar assemblies that consist of a framework of metal bars or wires arranged to provide rigid support for the dowels throughout the paving operation, with a minimum of four continuous bars or wires extending along the joint line. Provide dowels that are welded to the assembly or held firmly by mechanical locking arrangements that prevent them from rising, sliding out, or becoming distorted during paving operations.

2.10 EPOXY RESIN

Provide epoxy-resin materials that consist of two-component materials conforming to the requirements of ASTM C881/C881M, Class as appropriate for each application temperature to be encountered, except that in addition, the materials meet the following requirements:

- a. Type IV, Grade 3 for use for embedding dowels and anchor bolts.
- b. Type III, Grade as required for use as patching materials for complete filling of spalls, saw-cut runouts, and other voids and for use in preparing epoxy resin mortar.
- c. Type IV, Grade 1 for use for injecting cracks.
- d. Type V, Grade as required for bonding freshly mixed Portland cement concrete or mortar or freshly mixed epoxy resin concrete or mortar to hardened concrete.

2.11 EQUIPMENT

Maintain all plant, equipment, tools, and machines used in the work in satisfactory working conditions at all times. Submit the following:

- a. Details and data on the batching and mixing plant prior to plant assembly including manufacturer's literature showing that the equipment meets all requirements specified herein.
- b. Obtain National Ready Mixed Concrete Association (NRMCA) certification of the concrete plant, at no expense to the Government. Provide inspection report of the concrete plant by an engineer approved by the NRMCA. The NRMCA certified engineer cannot be employed by the primary contractor or a subcontractor. A list of NRMCA approved engineers is available on the NRMCA website at <http://www.nrmca.org>. Submit a copy of the NRMCA QC Manual Section 3 Concrete Plant Certification Checklist, NRMCA Certificate of Conformance, and Calibration documentation on all measuring and weighing devices prior to uniformity testing.
- c. A description of the equipment proposed for transporting concrete mixture from the central mixing plant to the paving equipment.
- d. A description of the equipment proposed for the machine and hand placing, consolidating and curing of the concrete mixture. Manufacturer's literature on the paver and finisher, together with the manufacturer's written instructions on adjustments and operating procedures necessary to assure a tight, smooth surface on the concrete pavement. The literature is required to show that the equipment meets all details of these specifications. Include detailed information on automatic laser controlled systems if proposed for use.

2.11.1 Batching and Mixing Plant

2.11.1.1 Location

Locate the batching and mixing plant off Government premises no more than 30 minutes haul and gate security check time from the placing site. Provide operable telephonic or radio communication between the plant and the placing site at all times concreting is taking place.

2.11.1.2 Type and Capacity

Provide a batching and mixing plant consisting of a stationary-type central mix plant, including permanent installations and portable or relocatable plants installed on stable foundations. Provide a plant designed and operated to produce concrete within the specified tolerances, with a minimum capacity of 250 cubic yards per hour, that conforms to the requirements of NRMCA QC 3 including provisions addressing:

1. Material Storage and Handling
2. Batching Equipment
3. Central Mixer
4. Ticketing System
5. Delivery System

2.11.1.3 Tolerances

TABLE 9	
BATCH PLANT MIXING TOLERANCES	
Materials	Percentage of Required Mass
Cementitious Materials	plus or minus 1
Aggregate	plus or minus 2
Water	plus or minus 1
Admixture	plus or minus 3

For volumetric batching equipment for water and admixtures, the above numeric tolerances apply to the required volume of material being batched. Dilute concentrated admixtures uniformly, if necessary, to provide sufficient volume per batch so that the batchers operate consistently within the above tolerance.

2.11.1.4 Moisture Control

Provide a plant capable of ready adjustment to compensate for the varying moisture contents of the aggregates and to change the quantities of the materials being batched. Provide an electric moisture meter complying with the provisions of COE CRD-C 143 for measuring of moisture in the fine aggregate. Provide a sensing element arranged so that measurement is made near the batcher charging gate of the fine aggregate bin or in the fine aggregate batcher.

2.11.2 Concrete Mixers

Provide stationary or truck mixers that are capable of combining the materials into a uniform mixture and of discharging this mixture without segregation. Do not charge the mixers in excess of the capacity recommended by the manufacturer. Operate the mixers at the drum or mixing blade speed designated by the manufacturer. Maintain the mixers in satisfactory operating condition, with the mixer drums kept free of hardened concrete. Replace mixer blades or paddles when worn down more than 10 percent of their depth when compared with the manufacturer's dimension for new blades or paddles.

2.11.2.1 Stationary Mixers

Stationary mixers are required to be drum or pan mixers. Provide mixers with an acceptable device to lock the discharge mechanism until the required mixing time has elapsed. Perform mixer performance (uniformity) testing in accordance with COE CRD-C 55 and with paragraph TESTING AND INSPECTION FOR CONTRACTOR QUALITY CONTROL DURING CONSTRUCTION in PART 3.

2.11.2.1.1 Mixing Time and Uniformity for Stationary Mixers

Use the project's approved mixture proportions for uniformity testing. For stationary mixers, before uniformity data are available, the minimum mixing time for each batch after all solid materials are in the mixer, provided that all of the mixing water is introduced before one-fourth of the mixing time has elapsed, is 1 minute for mixers having a capacity of 1 cubic yard. For mixers of greater capacity, increase this minimum time by 20 seconds for each additional 1.33 cubic yard or fraction thereof. Provide uniformity test results meeting the properties required by this specification in addition to meeting the requirements of Table 10. After results of uniformity tests are available, the mixing time may be reduced to the minimum time required to meet uniformity requirements; but if uniformity requirements are not being met, increase the mixing time as directed. Perform mixer uniformity tests at new mixing times immediately after any change in mixing time or volume. Any changes to the mix constituents or sequence of charging the mixer after a batch requires an additional three consecutive passing batches. For regular testing perform all six tests on three consecutive batches of concrete. The range for regular testing is the average of the ranges of the three consecutive batches. Conduct the Regular Test sequence for initial determination of the mixing time or as directed. When regular testing is performed, the concrete is required to meet the limits of any five of the six uniformity requirements listed in Table 10 below.

2.11.2.1.2 Abbreviated Uniformity Test

Use the project's approved mixture proportions for uniformity testing. Conduct the Abbreviated Test sequence for production concrete verification at the frequency specified in Table 16. Provide uniformity test results meeting the fresh and hardened concrete properties required by this specification in addition to meeting the requirements of Table 10. When abbreviated testing is performed, the concrete is required to meet only those requirements listed for abbreviated testing. Abbreviated testing is performed on a single batch of concrete. The range for abbreviated testing is the range for one batch. If more than one mixer is used and all are identical in terms of make, type, capacity, condition, speed of rotation, the results of tests on one of the mixers apply to the others, subject to Government approval.

TABLE 10		
UNIFORMITY REQUIREMENTS--STATIONARY MIXERS		
Parameter	Regular Tests Allowable Maximum Range for 3 Consecutive Batches	Abbreviated Tests Allowable Maximum Range for 1 Batch
Unit weight of air-free mortar	2.0 pounds per cubic foot	2.0 pounds per cubic foot
Air content	1.0 percent	Not Applicable
Slump	1.0 inch	1.0 inch
Coarse aggregate	6.0 percent	6.0 percent
Compressive strength at 7 days	10.0 percent	10.0 percent
Water content	1.5 percent	Not Applicable

2.11.2.2 Truck Mixers

Truck mixers are not allowed for mixing or transporting slipformed paving concrete. Provide only truck mixers designed for mixing or transporting paving concrete with extra large blading and rear opening specifically for low-slump paving concrete. Provide truck mixers, the mixing of concrete therein, and concrete uniformity and testing thereof that conform to the requirements of ASTM C94/C94M. Any changes to the mix constituents or sequence of charging the truck mixer requires an additional three consecutive passing batches. Determine the number of revolutions between 70 to 100 for truck-mixed concrete and the number of revolutions for shrink-mixed concrete by uniformity tests as specified in ASTM C94/C94M and in requirements for mixer performance stated in paragraph TESTING AND INSPECTION FOR CONTRACTOR QUALITY CONTROL DURING CONSTRUCTION in PART 3. If requirements for the uniformity of concrete are not met with 100 revolutions of mixing after all ingredients including water are in the truck mixer drum, discontinue use of the mixer until the condition is corrected. Water is not allowed to be added after the initial introduction of mixing water except, when on arrival at the job site, the slump is less than specified and the water-cement ratio is less than that given as a maximum in the approved mixture. Additional water may be added to bring the slump within the specified range provided the approved water-cement ratio is not exceeded. Inject water into the head of the mixer (end opposite the discharge opening) drum under pressure, and turn the drum or blades a minimum of 30 additional revolutions at mixing speed. The addition of water to the batch at any later time is not allowed.

2.11.3 Transporting Equipment

Transport slipform concrete to the paving site in non-agitating equipment conforming to ASTM C94/C94M or in approved open top agitators. Truck mixers are not allowed for mixing or transporting slipformed paving concrete. Transport fixed form concrete in non-agitating equipment or approved truck mixers designed with extra large blading and rear opening specifically for low slump concrete. Provide transporting equipment

designed and operated to deliver and discharge the required concrete mixture completely without segregation.

2.11.4 Transfer and Spreading Equipment

Provide a Material Transfer Vehicle (MTV) capable of moving between the hauling equipment and the paver and equipped with a swing conveyor that delivers material to the paver from outside the paving lane without making contact with the paver while allowing the paver to operate at a constant speed.

2.11.5 Paver-Finisher

Provide paver-finisher consisting of a heavy-duty, self-propelled machine designed specifically for paving and finishing high quality pavement, with a minimum weight of 2200 pounds per foot of lane width, and powered by an engine having a minimum 6.0 horsepower per foot of lane width. The paver-finisher is required to spread, consolidate, and shape the plastic concrete to the desired cross section in one pass. The mechanisms for forming the pavement are required to be easily adjustable in width and thickness. In addition to other spreaders required by paragraph above, equip the paver-finisher with a full width knock-down auger or plow mechanism, capable of operating in both directions, which evenly spreads the fresh concrete in front of the screed or extrusion plate.

2.11.5.1 Vibrators

Provide gang mounted immersion vibrators at the front of the paver on a frame equipped with suitable controls so that all vibrators can be operated at any desired depth within the slab or completely withdrawn from the concrete, as required. Provide vibrators that are automatically controlled to immediately stop as forward motion of the paver ceases. Equip the paver-finisher with an electronic vibrator monitoring device displaying the operating frequency of each individual internal vibrator with a readout display visible to the paver operator that operates continuously while paving, and displays all vibrator frequencies with manual or automatic sequencing among all individual vibrators. Discontinue paving if the vibrator monitoring system fails to operate properly during the paving operation. Provide the spacing of the immersion vibrators across the paving lane as necessary to properly consolidate the concrete, with a maximum clear distance between vibrators of 30 inches and outside vibrators a maximum of 12 inches from the lane edge. Determine vibrator frequency and amplitude per COE CRD-C 521.

2.11.5.2 Screed or Extrusion Plate

Equip the paver-finisher with a transversely oscillating screed or an extrusion plate to shape, compact, and smooth the surface and finish the surface that no significant amount of hand finishing, except use of cutting straightedges, is required. Provide adjustment for variation in lane width or thickness and to prevent more than 8 inches of the screed or extrusion plate extending over previously placed concrete on either side when paving fill-in lanes. Repair or replace machines that cause displacement of properly installed forms or cause ruts or indentations in the prepared underlying materials and machines that cause frequent delays due to mechanical failures.

2.11.5.3 Longitudinal Mechanical Float

A longitudinal mechanical float may be used. If used, provide a float that is specially designed and manufactured to smooth and finish the pavement surface without working excess paste to the surface and is rigidly attached to the rear of the paver-finisher or to a separate self-propelled frame spanning the paving lane. Provide float plate at least 5 feet long by 8 inches wide that automatically oscillates in the longitudinal direction while slowly moving from edge to edge of the paving lane, with the float plate in contact with the surface at all times.

2.11.5.4 Other Types of Finishing Equipment

Clary screeds (triple drum roller screeds), other rotating tube floats, or bridge deck finishers are not allowed on mainline paving, but may be allowed on irregular or odd-shaped slabs, and near buildings or trench drains, subject to approval. Only use vibrating screeds or pans for isolated slabs where hand finishing is permitted as specified, and only where specifically approved.

2.11.5.5 Fixed Forms

Provide paver-finisher equipped with wheels designed to ride the forms, keep it aligned with the forms, and spread the load so as to prevent deformation of the forms. When traveling on new or existing concrete to remain, provide paver-finishers traveling on guide rails located outside of the paving lane that are equipped with wheels that will not cause damage or spalling to concrete joint edges to remain. Alternatively, a modified slipform paver that straddles the forms may be used. Provide a modified slipform paver which has the side conforming plates removed or rendered ineffective and travels over or along pre-placed fixed forms.

2.11.5.6 Slipform

Provide an automatically controlled slipform paver-finisher that is crawler mounted with padded tracks so as to be completely stable under all operating conditions and provide a finish to the surface and edges so that no edge slump beyond allowable tolerance occurs. Provide suitable moving side forms that are adjustable and produce smooth, even edges, perpendicular to the top surface and meeting specification requirements for alignment, edge slump, and joint face deformation.

2.11.6 Curing Equipment

Provide equipment for applying membrane-forming curing compound mounted on a self-propelled frame that spans the paving lane. Constantly agitate the curing compound reservoir mechanically (not air) during operation and provide a means for completely draining the reservoir. Provide a spraying system that consists of a mechanically powered pump which maintains constant pressure during operation, an operable pressure gauge, and either a series of spray nozzles evenly spaced across the lane to provide uniformly overlapping coverage or a single spray nozzle which is mounted on a carriage which automatically traverses the lane width at a speed correlated with the forward movement of the overall frame. Protect all spray nozzles with wind screens. Calibrate the spraying system in accordance with ASTM D2995, Method A, for the rate of application required in paragraph MEMBRANE CURING. Provide hand-operated sprayers allowed by that paragraph with compressed air supplied by a mechanical air compressor. Immediately replace curing equipment if it fails to apply an

even coating of compound at the specified rate.

2.11.7 Texturing Equipment

Provide texturing equipment as specified below. Before use, demonstrate the texturing equipment on the test section, and modify the equipment as necessary to produce the texture directed.

2.11.7.1 Burlap Drag

Securely attach a burlap drag to a separate wheel mounted frame spanning the paving lane or to one of the other similar pieces of equipment. Provide length of the material between 24 to 36 inches dragging flat on the pavement surface and with a width at least equal to the width of the slab. Provide clean, reasonably new burlap material, completely saturated with water before attachment to the frame, moistened before start of use, and kept clean and maintained moist during use. Provide burlap conforming to AASHTO M 182, Class 3 or 4.

2.11.8 Sawing Equipment

Provide equipment for sawing joints and for other similar sawing of concrete consisting of standard diamond-type concrete saws mounted on a wheeled chassis which can be easily guided to follow the required alignment. Provide diamond tipped blades. If demonstrated to operate properly, abrasive blades may be used. Provide spares as required to maintain the required sawing rate. Provide wheel saws used in the removal of concrete with large diameter tungsten carbide tipped blades mounted on a heavy-duty chassis which produce a saw kerf at least 1-1/2 inches wide. Provide saws capable of sawing to the full depth required. Early-entry saws may be used, subject to demonstration and approval. No change to the initial sawcut depth is permitted.

2.11.9 Straightedge

Provide and maintain at the job site, in good condition, a minimum 12-foot straightedge for each paving train for testing the hardened Portland cement concrete surfaces. Provide straightedges constructed of aluminum or magnesium alloy and blades of box or box-girder cross section with flat bottom, adequately reinforced to maintain rigidity and accuracy. Provide straightedges with handles for operation on the pavement.

2.11.10 Work Bridge

Provide a self-propelled work bridge capable of spanning the required paving lane width where workmen can efficiently and adequately reach the pavement surface.

2.11.11 Hand Finishing Tools

Provide hand finishing equipment in accordance with the provisions of this specification. Use the hand method only on isolated areas of odd slab widths or shapes and in the event of a breakdown of the mechanical finishing equipment. Keep supplemental hand finishing for machine finished pavement to an absolute minimum. Do not seal the paving surface with steel trowels.

2.12 SPECIFIED CONCRETE STRENGTH AND OTHER PROPERTIES

2.12.1 Specified Flexural Strength

Specified flexural strength, R, for concrete is 650 psi at 90 days, as determined by historical tests made in accordance with ASTM C78/C78M of beams fabricated and cured in accordance with ASTM C192/C192M.

2.12.2 Allowable Water-Cementitious Materials Ratio

The allowable water-cementitious material ratio is 0.38 to 0.45. The water-cementitious material ratio is the equivalent water-cement ratio as determined by conversion from the weight ratio of water to cement plus SCM by the mass equivalency method described in ACI 211.1.

2.12.3 Air Content

Provide concrete that is air-entrained with a total air content of 6.0 plus or minus 1.5 percentage points, at the point of placement. Determine air content in accordance with ASTM C231/C231M.

2.12.4 Slump

The maximum allowable slump of the concrete at the point of placement is listed in Table 11.

TABLE 11	
MAXIMUM ALLOWABLE SLUMP	
Placement Method	Maximum Slump
Slipform	As required to meet edge slump and joint face deformation limits
Fixed Form	2 inches
Other Types of Finishing Equipment	3 inches
Hand Placement	3 inches

The selected slump is applicable to both pilot and fill-in lanes. Perform separate trial mixture studies for each placement method, as specified in paragraph Trial Mixture Studies.

2.12.5 Concrete Temperature

The temperature of the concrete as delivered is required to conform to the requirements of paragraphs Paving In Hot Weather and Paving In Cold Weather. Determine the temperature of concrete in accordance with ASTM C1064/C1064M.

2.12.6 Concrete Strength for Final Acceptance

The strength of the concrete will be considered acceptable when the equivalent 90-day flexural strengths for each lot are above the 'Specified Flexural Strength' as determined by correlation with 14-day flexural strength tests specified in paragraph Mixture Proportioning For Flexural

Strength below, and no individual set (2 specimens per subplot) in the lot are 25 psi or more below the equivalent 'Specified Flexural Strength'. If any lot or subplot, respectively, fails to meet the above criteria, remove and replace the lot or subplot at no additional cost to the Government. This is in addition to and does not replace the average strength required for day-to-day CQC operations as specified in paragraph Average Cqc Flexural Strength Required For Mixtures, below.

2.13 MIXTURE PROPORTIONS

2.13.1 Mixture Proportions Composition

Provide concrete composed of cementitious material, water, fine and coarse aggregates, and admixtures. Include supplementary Cementitious Materials (SCM) choice and usage in accordance with paragraph Supplementary Cementitious Materials (SCM) Content. Provide a minimum total cementitious materials content of 470 pounds per cubic yard. Limit the total alkali loading contributed by the Portland cement or the Portland cement portion of a blended cement to a maximum of 3.0 lb per cubic yard. Calculate the alkali loading as the product of the portland cement content of the concrete multiplied by the alkali content of the portland cement or the portland cement portion of the blended cement, divided by 100. Determine the alkali content in accordance with ASTM C114. Acceptable admixtures consist of air entraining admixture and may also include, as approved, water-reducing admixture, retarding admixture, retarding admixtures, water reducing and accelerating admixtures.

2.13.2 Proportioning Studies

Perform trial design batches, mixture proportioning studies, and testing, at no expense to the Government. Submit for approval the Preliminary Proposed Proportioning to include items a., b., and i. below a minimum of 21 days prior to beginning a mixture proportioning study. Submit the results of the mixture proportioning studies signed and stamped by the registered professional engineer having technical responsibility for the mix design study, and submitted at least 30 days prior to commencing concrete placing operations. Include a statement summarizing the maximum nominal coarse aggregate size and the weights and volumes of each ingredient proportioned on a one cubic yard basis. Base aggregate quantities on the mass in a saturated surface dry condition. Provide test results demonstrating that the proposed mixture proportions produce concrete of the qualities indicated. Base methodology for trial mixtures having proportions, slumps, and air content suitable for the work as described in ACI 211.1, modified as necessary to accommodate flexural strength. ACI 211.1 can be supplemented with ACI 325.14R. Submit test results including:

- a. Individual coarse and fine aggregate gradations and plots. Include historic gradation averages and standard deviations on individual sieves for each aggregate size group.
- b. Combined aggregate gradation and coarseness vs. workability plots.
- c. Coarse aggregate quality test results.
- d. Fine aggregate quality test results.
- e. Mill certificates for cement and supplementary cementitious materials.
- f. Certified test results for air entraining, water reducing, retarding, non-chloride accelerating, and Lithium Nitrate admixtures.
- g. Specified flexural strength, slump, and air content.
- h. Documentation of required average CQC flexural strength, Ra.
- i. Recommended proportions and volumes for proposed mixture and each of

three trial water-cementitious materials ratios for each proposed placement method.

- j. Individual beam breaks.
- k. Flexural strength summaries and plots.
- l. Correlation ratios for acceptance testing and CQC testing.
- m. Historical record of ACI 214R strength test results, documenting production standard deviation (if available).
- n. Narrative discussing methodology on how the mix design was developed in accordance with ACI 211.1 and ACI 325.14R.
- o. Alternative aggregate blending to be used during the test section if necessary to meet the required surface and consolidation requirements.

2.13.2.1 Water-Cementitious Materials Ratio

Perform at least three different water-cementitious materials ratios, within the limits specified in paragraph Allowable Water-Cementitious Materials Ratio, which produce a range of strength encompassing that required on the project. The minimum and maximum water-cementitious materials ratios of the approved mix design become the minimum and maximum water-cementitious materials ratio for the project during production.

2.13.2.2 Trial Mixture Studies

Perform separate sets of trial mixture studies made for each combination of cementitious materials and each combination of admixtures proposed for use. No combinations are to be used until proven by such studies, except that, if approved in writing and otherwise permitted by these specifications, an accelerating or retarding admixture can be used without separate trial mixture study. Perform separate trial mixture studies for each placing method (slip form, fixed form, or hand placement) proposed. Report the temperature of concrete in each trial batch. Design each mixture to promote easy and suitable concrete placement, consolidation and finishing, and to prevent segregation and excessive bleeding. Proportion laboratory trial mixtures for maximum slump and air content, as permitted by the placement method being utilized.

2.13.2.3 Mixture Proportioning for Flexural Strength

Follow the step-by-step procedure below:

- a. Fabricate all beams for each mixture from the same batch or blend of batches. Fabricate and cure all beams in accordance with ASTM C192/C192M, using 6 x 6 inches steel beam molds.
- b. Cure test beams from each mixture for 3, 7, 14, 56 and 90-day flexural tests; 6 beams to be tested per age.
- c. Test beams in accordance with ASTM C78/C78M.
- d. Using the average strength for each w/c at each age, plot all results from each of the three mixtures on separate graphs for w/c versus:
 - 3-day flexural strength
 - 7-day flexural strength
 - 14-day flexural strength
 - 56 and 90-day flexural strength
- e. From these graphs select a w/c that produces a mixture giving a 90-day flexural strength equal to the required strength determined in accordance with paragraph Average CQC Flexural Strength Required for

Mixtures.

- f. Using the above selected w/c, select from the graphs the expected 3, 7 and 14-day flexural strengths.
- g. From the above expected strengths for the selected mixture, determine the Ratio of the 7-day flexural strength of the selected mixture to the 90-day flexural strength of the mixture (for CQC control).
- h. From the above expected strengths for the selected mixture, determine the Ratio of the 14-day flexural strength of the selected mixture to the 90-day flexural strength of the mixture (for acceptance).
- i. If there is a change in materials, perform additional mixture design studies using the new materials and determine new Correlation Ratios.
- j. No concrete pavement placement is allowed until the mixture proportions are approved. The approved water-cementitious materials ratio is restricted to the minimum and maximum values specified in paragraph Water-Cementitious Materials Ratio and is not to be increased without written approval.

2.13.3 Average CQC Flexural Strength Required for Mixtures

- a. In order to meet the strength requirements specified in paragraph SPECIFIED CONCRETE STRENGTH AND OTHER PROPERTIES during production, the mixture proportions selected during mixture proportioning studies and used during construction require an average CQC flexural strength, R_a , exceeding the specified flexural strength, R , by the amount indicated below.
- b. The required average CQC flexural strength, R_a , is used only for proportioning studies and CQC operations as specified in paragraph Concrete Strength Testing for CQC.
- c. Acceptance of production flexural strength results is based on the specified flexural strength R specified in paragraph: Specified Flexural Strength.

2.13.3.1 From Previous Test Records

Where a concrete production facility has previous test records current to within 18 months, establish a standard deviation in accordance with the applicable provisions of ACI 214R. Include test records from which a standard deviation is calculated that represent materials, quality control procedures, and conditions similar to those expected, that represent concrete produced to meet a specified flexural strength or strengths within 150 psi of the 90-day flexural strength specified for the proposed work, and that consist of at least 30 consecutive tests. Perform verification testing to document the current strength. A strength test is the average of the strengths of two specimens made from the same sample of concrete and tested at 90 days. Required average CQC flexural strength, R_a , used as the basis for selection of concrete proportions is the value from the equation that follows, using the standard deviation as determined above:

$$R_a = R + 1.34S$$

Where: S = standard deviation
 R = specified flexural strength

Ra = required average CQC flexural strength

Where a concrete production facility does not have test records meeting the requirements above but does have a record based on 15 to 29 consecutive tests, establish a standard deviation as the product of the calculated standard deviation and a modification factor from Table 12:

TABLE 12	
MODIFICATION FACTOR FOR STANDARD DEVIATION	
NUMBER OF TESTS	MODIFICATION FACTOR
20	1.08
25	1.03
30 or more	1.00

2.13.3.2 Without Previous Test Records

When a concrete production facility does not have sufficient field strength test records for calculation of the standard deviation, determine the required average CQC flexural strength, Ra, by adding 15 percent to the specified flexural strength, R.

PART 3 EXECUTION

3.1 PREPARATION FOR PAVING

Before commencing paving, perform the following actions to prepare for paving operations. If used, place cleaned, coated, and adequately supported forms. Have any reinforcing steel needed at the paving site; all transporting and transfer equipment ready for use, clean, and free of hardened concrete and foreign material; equipment for spreading, consolidating, screeding, finishing, and texturing concrete at the paving site, clean and in proper working order; and all equipment and material for curing and for protecting concrete from weather or mechanical damage at the paving site, in proper working condition, and in sufficient amount for the entire placement.

3.1.1 Weather Precaution

When windy conditions during paving appear probable, have equipment and material at the paving site to provide windbreaks, shading, fogging, or other action to prevent plastic shrinkage cracking or other damaging drying of the concrete. During these conditions, record and report the evaporation rate hourly.

3.1.2 Proposed Techniques

Submit placing and protection methods; paving sequence; jointing pattern; data on curing equipment and straightedge; repair in accordance with paragraph REPAIR, REMOVAL AND REPLACEMENT OF NEWLY CONSTRUCTED SLABS, demolition of existing pavements, as specified; pavement diamond grinding equipment and procedures. Submit for approval the following items:

- a. Pavement demolition work plan, presenting the proposed methods and equipment to remove existing pavement and protect pavement to remain

in place.

- b. A description of the placing and protection methods proposed when concrete is to be placed in or exposed to hot, cold, or inclement weather conditions
- c. A detailed paving sequence plan and proposed paving pattern showing all planned construction joints; transverse and longitudinal dowel bar spacing; and identifying pilot lanes, fill-in lanes, and hand placement areas. Include stationing for reference to all sampling and testing performed. Deviations from the jointing pattern shown on the drawings are not allowed without written approval of the design engineer.
- d. Plan and equipment proposed to control alignment of sawn joints within the specified tolerances.
- e. Data on the curing equipment, media and methods to be used.
- f. Data on straightedge and methods to measure pavement smoothness.
- g. A description of the equipment and methods to be used for grinding and repairs.

3.2 CONDITIONING OF UNDERLYING MATERIAL

3.2.1 General Procedures

Confirm the underlying material upon which concrete is to be placed is clean, damp, and free from debris, waste concrete or cement, frost, ice, and standing or running water. Prior to setting forms or placement of concrete, confirm the underlying material is well drained and has been satisfactorily graded and uniformly compacted in accordance with the applicable contract documents. Test the surface of the underlying material to crown, elevation, and density in advance of setting forms or of concrete placement using slip-form techniques. Trim high areas to proper elevation. Fill and compact low areas to a condition similar to that of surrounding grade or fill with concrete monolithically with the pavement. Low areas filled with concrete are not to be cored for thickness to avoid biasing the average thickness used for evaluation and payment adjustment. Rework and compact any underlying material disturbed by construction operations to specified density immediately in front of the paver. If a slipform paver is used, continue the same underlying material beyond the edge of the lane a sufficient distance to provide a suitable trackline for the slipform paver and firm support for the edge of the paving lane.

3.2.2 Traffic on Underlying Material

After the underlying material has been prepared for concrete placement, equipment is not permitted thereon with exception of the paver. Subject to specific approval, crossing of the prepared underlying material at specified intervals for construction purposes may be permitted, provided rutting or indentations do not occur. Rework and repair the surface before concrete is placed. Transporting equipment is not to be allowed to operate on the prepared and compacted underlying material in front of the paver-finisher.

3.3 WEATHER LIMITATIONS

3.3.1 Placement and Protection During Inclement Weather

Do not commence placing operations when heavy rain or other damaging weather conditions appear imminent. At all times when placing concrete, maintain on-site sufficient waterproof cover and means to rapidly place it over all unhardened concrete or concrete that might be damaged by rain. Immediately cover and protect all unhardened concrete from rain or other damaging weather. Suspend placement of concrete whenever rain, high winds, or other weather commences to damage the surface or texture of the placed unhardened concrete, washes cement out of the concrete, or changes the water content of the surface concrete.

Remove and replace any slab damaged by rain or other weather, as defined in paragraph Weak Surfaces, full depth, by full slab width, to the nearest original joint as specified in paragraph REPAIR, REMOVAL AND REPLACEMENT OF NEWLY CONSTRUCTED SLABS, at no expense to the Government.

3.3.2 Paving in Hot Weather

Prepare for hot weather paving in accordance with ACI 305R. When the ambient temperature during paving is expected to exceed 90 degrees F, properly place and finish the concrete in accordance with procedures previously submitted, approved, and as specified herein. Provide concrete that does not exceed the temperature shown in Table 13 below when measured in accordance with ASTM C1064/C1064M at the time of delivery. Cool the mixing water or aggregates or place in the cooler part of the day to obtain an adequate placing temperature. Cool steel forms and reinforcing as needed to maintain steel temperatures below 120 degrees F. Cool or protect transporting and placing equipment if necessary to maintain proper concrete placing temperature. Keep the finished surfaces of the newly laid pavement damp by applying a fog spray (mist) with approved spraying equipment until the pavement is covered by the curing medium.

Maximum Allowable Concrete Placing Temperature	
Relative Humidity, Percent, During Time of Concrete Placement	Maximum Allowable Concrete Temperature in Degrees F
Greater than 60	90
55-60	85
Less than 55	75

3.3.3 Prevention of Plastic Shrinkage Cracking

During weather with low humidity, and particularly with high temperature and appreciable wind, develop and institute measures to prevent plastic shrinkage cracks from developing. If plastic shrinkage cracking occurs, halt further placement of concrete until protective measures are in place to prevent further cracking. Periods of high potential for plastic shrinkage cracking can be anticipated by use of ACI 305R. In addition to the protective measures specified in the previous paragraph, further

protect the concrete placement by erecting shades and windbreaks and by applying fog sprays of water, the addition of monomolecular films, or wet covering. If monomolecular films are used, apply only after finishing is complete, do not use in the finishing process, and follow manufacturer recommendations. Immediately commence curing procedures when such water treatment is stopped. Repair plastic shrinkage cracks in accordance with paragraph REPAIR, REMOVAL AND REPLACEMENT OF NEWLY CONSTRUCTED SLABS. Never trowel over or fill plastic shrinkage cracks with slurry.

3.3.4 Paving in Cold Weather

Cold weather paving is required to conform to ACI 306R. Use special protection measures, as specified herein, if freezing temperatures are anticipated or occur before the expiration of the specified curing period. Do not begin placement of concrete unless the ambient temperature is at least 35 degrees F and rising. Thereafter, halt placement of concrete whenever the ambient temperature drops below 40 degrees F. When the ambient temperature is less than 50 degrees F, the temperature of the concrete when placed is required to be not less than 50 degrees F nor more than 75 degrees F. Provide heating of the mixing water or aggregates as required to regulate the plastic concrete temperature. Provide materials entering the mixer that are free from ice, snow, or frozen lumps. Do not incorporate salt, chemicals or other materials in the concrete to prevent freezing. Provide covering and other means for maintaining the concrete at a temperature of at least 10 degrees C 50 degrees F for not less than 72 hours after placing, and at a temperature above freezing for the remainder of the curing period as defined in paragraph Protection of Concrete. Remove pavement slabs, full depth by full width, damaged by freezing or falling below freezing temperature to the nearest planned joint, and replace as specified in paragraph REPAIR, REMOVAL AND REPLACEMENT OF NEWLY CONSTRUCTED SLABS, at no expense to the Government.

3.4 CONCRETE PRODUCTION

Maintain a continuous, uniform forward movement of the paver of not less than 2.5 feet per minute. Provide batching, mixing, and transporting equipment with a capacity sufficient to meet this production rate. Deposit concrete transported in non-agitating equipment in front of the paver within 45 minutes from the time cement has been charged into the mixing drum, except that if the ambient temperature is above 90 degrees F, the time is reduced to 30 minutes. Deposit concrete transported in truck mixers in front of the paver within 90 minutes from the time cement has been charged into the mixer drum of the plant or truck mixer. Truck mixers are not allowed for mixing or transporting slipformed paving concrete. If the ambient temperature is above 90 degrees F, the time is reduced to 60 minutes. Accompany every load of concrete delivered to the paving site with a batch ticket from the operator of the batching plant. Provide batch ticket information required by ASTM C94/C94M on approved forms. In addition, provide design quantities in mass or volume for all materials, batching tolerances of all materials, mixture batching time, and design and actual water cementitious materials ratio on each batch delivered, the water meter and revolution meter reading on truck mixers and the time of day on all batch tickets. Provide batch tickets for each truck delivered as part of the lot acceptance package to the placing foreman to maintain on file and deliver them to the Government weekly.

3.4.1 Batching and Mixing Concrete

Remove any equipment which fails to perform as specified immediately from

use until properly repaired and adjusted or replaced.

3.4.2 Transporting and Transfer - Spreading Operations

Operate non-agitating equipment only on smooth roads and for haul time less than 30 minutes. Deposit concrete as close as possible to its final position in the paving lane using a transfer-spreader. Operate all equipment to discharge and transfer concrete without segregation. Dumping of concrete in discrete piles is not permitted. No transfer or spreading operation which requires the use of front-end loaders, dozers, or similar equipment to distribute the concrete is permitted. No equipment is permitted to operate on the grade in front of the paver.

3.5 PAVING

3.5.1 General Requirements

Construct pavement with paving and finishing equipment utilizing rigid fixed forms or by use of slipform paving equipment. Provide paving and finishing equipment and procedures resulting in paving lanes of the required width at a rate of at least 2.5 feet of paving lane per minute on a routine basis. Control paving equipment and its operation, and coordinate with all other operations, such that the paver-finisher has a continuous forward movement at a reasonably uniform speed from beginning to end of each paving lane, except for inadvertent equipment breakdown. Backing the paver and refinishing a lane is not permitted. Remove and replace concrete refinished in this manner. Failure to achieve a continuous forward motion requires halting operations, and modifying procedures, equipment, or mix proportions to achieve this requirement. Personnel are not permitted to walk or operate in the plastic concrete at any time. Select paving equipment and procedures which operate properly on the underlying material without causing displacement or other damage.

3.5.2 Consolidation

Consolidate concrete with the specified type of lane-spanning, gang-mounted, mechanical, immersion type vibrating equipment mounted in front of the paver, supplemented, in rare instances as specified, by hand-operated vibrators. Insert vibrators into the concrete to a depth that provides the best full-depth consolidation but not closer to the underlying material than 2 inches. Excessive vibration is not permitted. If vibrators cause visible tracking in the paving lane, discontinue paving operations until equipment and operations have been modified to prevent it. Consolidate concrete in small, odd-shaped slabs or in isolated locations inaccessible to the gang-mounted vibration equipment with an approved hand-operated immersion vibrator operated from a bridge spanning the area. Do not use vibrators to transport or spread the concrete. Do not operate hand-operated vibrators in the concrete at one location for more than 20 seconds. Insert hand-operated vibrators between 6 to 15 inches on centers. For each paving train, provide at least one additional vibrator spud, or sufficient parts for rapid replacement and repair of vibrators at the paving site at all times. Any evidence of inadequate consolidation (honeycomb along the edges, large air pockets, or any other evidence) requires the immediate stopping of the paving operation and approved adjustment of the equipment or procedures.

3.5.3 Operation

When the paver approaches a header at the end of a paving lane, maintain a

sufficient amount of concrete ahead of the paver to provide a roll of concrete which spills over the header. Provide a sufficient amount of extra concrete to prevent any grout that is formed and carried along ahead of the paver from being deposited adjacent to the header. Maintain the spud vibrators in front of the paver at the desired depth as close to the header as possible before they are lifted. Provide additional consolidation adjacent to the headers by hand-manipulated vibrators. When the paver is operated between or adjacent to previously constructed pavement (fill-in lanes), provide provisions to prevent damage to the adjacent pavement. Electronically control screeds or extrusion plates so as to prevent them from applying pressure to the existing pavement and to prevent abrasion of the pavement surface. Maintain the overlapping area of existing pavement surface completely free of any loose or bonded foreign material as the paver-finisher operates across it. Pavers using transversely oscillating screeds are not allowed to form fill-in lanes that have widths less than a full width for which the paver was designed or adjusted.

3.5.4 Required Results

Adjust and coordinate the paver-finisher, its gang-mounted vibrators, and operating procedures with the concrete mixture being used, to produce a thoroughly consolidated slab throughout that is true to line and grade within specified tolerances. Provide a paver-finishing operation that produces a surface finish with a minimum, isolated amount of irregularities, tears, voids of any kind, and any other discontinuities in a single pass across the pavement; multiple passes are not permitted. Provide equipment and its operation that produce a finished surface requiring no hand finishing other than the use of cutting straightedges, except in very infrequent instances. Stop paving if any equipment or operation fails to produce the above results. Prior to recommencing paving, properly adjust or replace the equipment, modify the operation, or modify the mixture proportions, in order to produce the required results. No water, other than fog sprays (mist) as specified in paragraph Prevention Of Plastic Shrinkage Cracking above, is allowed to be applied to the concrete or the concrete surface during paving and finishing.

3.5.5 Fixed Form Paving

Provide paving equipment for fixed-form paving and operation that conforms to the requirements of paragraph EQUIPMENT, and all requirements specified herein.

3.5.5.1 Forms for Fixed-Form Paving

- a. Provide straight forms made of steel and in sections not less than 10 feet in length that are clean and free of rust or other contaminants. Seal any holes or perforations in forms prior to paving unless otherwise permitted. Maintain forms in place and passable by all equipment necessary to complete the entire paving operation without need to remove horizontal form supports. Provide flexible or curved forms of proper radius for curves of 100-foot radius or less. Provide wood forms for curves and fillets made of well-seasoned, surfaced plank or plywood, straight, and free from warp or bend that have adequate strength and are rigidly braced. Provide forms with a depth equal to the pavement thickness at the edge. Where the project requires several different slab thicknesses, build up forms by bolting or welding a tubular metal section or by bolting wood planks to the bottom of the form to completely cover the underside of the base of

the form and provide an increase in depth of not more than 25 percent. Provide forms with the base width of the one-piece or built-up form not less than eight-tenths of the vertical height of the form, except provide forms 8 inches or less in vertical height with a base width not less than the vertical height of the form. Provide forms with maximum vertical deviation of top of any side form, including joints, not varying from a true plane more than 1/8 inch in 10 feet, and the upstanding leg not varying more than 1/4 inch.

- b. Provide form sections that are tightly locked and free from play or movement in any direction. Provide forms with adequate devices for secure settings so that when in place they withstand, without visible spring or settlement, the impact and vibration of the consolidating and finishing equipment.
- c. Set forms for full bearing on foundation for entire length and width and in alignment with edge of finished pavement. Support forms during entire operation of placing, consolidation, and finishing so that forms do not deviate vertically more than 0.01 foot from required grade and elevations indicated. Check conformity to the alignment and grade elevations shown on the drawings and make necessary corrections immediately prior to placing the concrete. Clean and oil the forms each time before concrete is placed. Concrete placement is not allowed until setting of forms has been checked and approved by the CQC team.
- d. Do not anchor guide rails for fixed form pavers into new concrete or existing concrete to remain.

3.5.5.2 Form Removal

Keep forms in place at least 12 hours after the concrete has been placed. When conditions are such that the early strength gain of the concrete is delayed, leave the forms in place for a longer time. Remove forms by procedures that do not damage the concrete. Do not use bars or heavy metal tools directly against the concrete in removing the forms. Promptly repair any concrete found to be defective after form removal, using procedures specified or as directed.

3.5.6 Slipform Paving

3.5.6.1 General

Provide paving equipment for slipform paving and the operation thereof that conforms to the requirement of paragraph EQUIPMENT, and all requirements specified herein. Provide a slipform paver capable of shaping the concrete in one pass to the specified and indicated cross section, meeting all tolerances, with a surface finish and edges that require only a very minimum isolated amount of hand finishing. If the paving operation does not meet the above requirements and the specified tolerances, immediately stop the operation and modify any equipment, paving procedures, or the concrete mix in order to resolve the problem. Provide a slipform paver that is automatically electronically controlled from a taut guideline for horizontal alignment and on both sides from a taut guideline for vertical alignment, except that electronic control from a ski operating on a previously constructed adjoining lane is required where applicable for either or both sides. Automatic, electronic controls are required for vertical alignment on both sides of the lane. Control from a slope-adjustment control or control operating from the underlying

material is not allowed. Properly adjust side forms on slipform pavers so that the finished edge of the paving lane meets all specified tolerances. Install dowels in longitudinal construction joints as specified below. The installation of these dowels by dowel inserters attached to the paver or by any other means of inserting the dowels into the plastic concrete is not permitted.

3.5.6.2 Guideline for Slipform Paving

Accurately and securely install guidelines well in advance of concrete placement. Provide supports at necessary intervals to eliminate all sag in the guideline when properly tightened. Provide guideline consisting of high strength material designed for use as a paving guideline with sufficient tension to remove all sag between supports. Provide supports that are securely staked to the underlying material or make other provisions to keep the supports from displacing when the guideline is tightened or when the guideline or supports are accidentally touched by workmen or equipment during construction. Provide appliances for attaching the guideline to the supports that are capable of easy adjustment in both the horizontal and vertical directions. When it is necessary to leave gaps in the guideline to permit equipment to use or cross underlying material, provide provisions for quickly and accurately replacing the guideline without any delay to the forward progress of the paver. Provide supports on either side of the gap that are secured in such a manner as to avoid disturbing the remainder of the guideline when the portion across the gap is positioned and tightened. Check the guideline across the gap and adjacent to the gap for a distance of 200 feet for horizontal and vertical alignment after the guideline across the gap is tightened. Provide vertical and horizontal positioning of the guideline such that the finished pavement conforms to the alignment and grade elevations shown on the drawings within the specified tolerances for grade and smoothness. The specified tolerances are intended to cover only the normal deviations in the finished pavement that occur under good supervision and do not apply to setting of the guideline. Set the guideline true to line and grade.

3.5.6.3 Stringless Technology

If the use of any type of stringless technology is proposed, submit a detailed description of the system and perform a trial field demonstration at least one week prior to start of paving. Approval of the control system will be based on the results of the demonstration and on continuing satisfactory operation during paving.

3.5.7 Placing Reinforcing Steel

Provide the type and amount of steel reinforcement indicated. Regardless of placement procedure, provide reinforcing steel free from coatings which could impair bond between the steel and concrete, with reinforcement laps as indicated. Regardless of the equipment or procedures used for installing reinforcement, adequately consolidate the entire depth of concrete. Install steel reinforcement at the required elevation within a tolerance of plus or minus 1/2 inch.

3.5.7.1 Pavement Thickness Greater Than 12 inches

For pavement thickness of 12 inches or more, place an initial lift of concrete on the underlying material to the required elevation of the steel reinforcement, consolidate the initial lift of concrete, place the steel

reinforcement upon the surface of the initial lift, place a second lift of concrete to final grade, consolidate, and finish in the required manner. When placement of the second lift causes the steel reinforcement to be displaced horizontally from its original position, provide provisions for increasing the thickness of the initial lift and depressing the steel reinforcement into the unhardened concrete to the required elevation. Limit the increase in thickness only as necessary to permit correct horizontal alignment to be maintained. Remove and replace any portions of the initial lift of concrete that have been placed more than 30 minutes without being covered with the second lift with newly mixed concrete without additional cost to the Government.

3.5.7.2 Pavement Thickness Less Than 12 Inches

For pavements less than 12 inches thick, position the reinforcement on suitable chairs or continuous mesh support devices securely fastened to the subgrade prior to concrete placement. Consolidate concrete after the steel has been placed.

3.5.8 Placing Dowels

Provide a method to install and hold dowels in position that meets the tolerances for location, alignment, and spacing of Table 14. Do not place longitudinal dowels closer than 0.6 times the dowel bar length to the planned joint line. If the last regularly spaced longitudinal dowel is closer than that dimension, move it away from the joint to a location 0.6 times the dowel bar length, but not closer than 6 inches to its nearest neighbor. Resolve dowel interference at a transverse joint-longitudinal joint intersection by deleting the closest transverse dowel. Do not position the end of a transverse dowel closer than 12 inches from the end of the nearest longitudinal dowel. Install dowels as specified in the following subparagraphs.

TABLE 14	
DOWEL ALIGNMENT TOLERANCES	
Dowel Measurement	Tolerance
Horizontal alignment (a)	Maximum of 1/8 inch per foot after the pavement has been completed
Vertical alignment (b)	Maximum of 1/8 inch per foot after the pavement has been completed
Horizontal spacing	plus or minus 5/8 inch, except as otherwise specified above
Vertical location on the face of the slab	plus or minus 1/2 inch
(a) Check horizontal alignment perpendicular to the joint edge with a framing square.	

TABLE 14	
DOWEL ALIGNMENT TOLERANCES	
Dowel Measurement	Tolerance
(b) Measure the vertical alignment of the dowels parallel to the designated top surface of the pavement, except for those across the crown or other grade change joints. Measure dowels across crowns and other joints at grade changes to a level surface.	

3.5.8.1 Contraction Joints

Securely hold dowels in longitudinal and transverse contraction joints within the paving lane in place, as indicated, by means of rigid metal frames or basket assemblies of an approved type. Securely hold the basket assemblies in the proper location by means of suitable pins or anchors. Do not cut or crimp the dowel basket tie wires.

3.5.8.2 Construction Joints-Fixed Form Paving

Install dowels by the bonded-in-place method or the drill-and-dowel method. Installation by removing and replacing in preformed holes is not permitted. Prepare and place dowels across joints where indicated, correctly aligned, and securely held in the proper horizontal and vertical position during placing and finishing operations, by means of devices fastened to the forms. Provide the spacing of dowels in construction joints as indicated, except that, where the planned spacing cannot be maintained because of form length or interference with form braces, provide closer spacing with additional dowels.

3.5.8.3 Dowels Installed in Hardened Concrete

Install dowels in hardened concrete by bonding the dowels into holes drilled into the hardened concrete. Before drilling commences, cure the concrete for 7 days or until it has reached a minimum field cured flexural strength of 450 psi. Drill holes 1/8 inch greater in diameter than the dowels into the hardened concrete using rotary-core drills. Rotary-percussion drills are permitted, provided that excessive spalling does not occur at the concrete joint face. Excessive spalling is defined as spalling deeper than 1/4 inch from the joint face or 1/2 inch radially from the outside of the drilled hole. Continuing damage requires modification of the equipment and operation. Drill depth of dowel hole within a tolerance of plus or minus 1/2 inch of the half length of the embedded dowel. Upon completion of the drilling operation, blow out the dowel hole with oil-free, compressed air. Bond dowels in the drilled holes using epoxy resin. Inject epoxy resin at the back of the hole before installing the dowel and extrude to the collar during insertion of the dowel so as to completely fill the void around the dowel. Application by buttering the dowel is not permitted. Hold the dowels in alignment at the collar of the hole, after insertion and before the grout hardens, by means of a suitable metal or plastic grout retention ring fitted around the dowel. Provide dowels required between new and existing concrete in holes drilled in the existing concrete, all as specified above.

3.5.8.4 Lubricating Dowel Bars

Wipe clean the portion of each dowel intended to move within the concrete and coat with a thin, even film of lubricating oil or light grease before

the concrete is placed. Form oil is not acceptable.

3.6 FINISHING

Provide finishing operations as a continuing part of placing operations starting immediately behind the paver. Provide finishing by the machine method. Hand finishing requirements are specified in paragraph HAND FINISHING. Provide the sequence of operations consisting of transverse finishing, longitudinal machine floating if used, straightedge finishing, texturing, and then edging of joints. Provide a work bridge as necessary for consolidation and hand finishing operations. Use the hand method only on isolated areas of odd slab widths or shapes and in the event of a breakdown of the mechanical finishing equipment. Keep supplemental hand finishing for machine finished pavement to an absolute minimum. Immediately stop any machine finishing operation which requires appreciable hand finishing, other than a moderate amount of straightedge finishing. Prior to recommencing machine finishing, properly adjust or replace the equipment. Immediately halt any operations which produce more than 1/8 inch of mortar-rich surface (defined in paragraph Weak Surfaces) and modify the equipment, mixture, or procedures as necessary. Compensate for surging behind the screeds or extrusion plate and settlement during hardening and adjust the paving and finishing machines so that the finished surface of the concrete (not just the cutting edges of the screeds) is at the required line and grade. Maintain finishing equipment and tools clean and in an approved condition. Water is not allowed to be added to the surface of the slab with the finishing equipment or tools, or in any other way, except for fog (mist) sprays specified to prevent plastic shrinkage cracking.

3.6.1 Machine Finishing With Fixed Forms

Replace machines that cause displacement of the forms. Only one pass of the fixed form finishing machine is allowed over each area of pavement. If the equipment and procedures do not produce a surface of uniform texture, true to grade, in one pass, immediately stop the operation and adjust the equipment, mixture, and procedures as necessary.

3.6.2 Machine Finishing with Slipform Pavers

Operate the slipform paver so that only a very minimum of additional finishing work is required to produce pavement surfaces and edges meeting the specified tolerances. Immediately modify or replace any equipment or procedure that fails to meet these specified requirements as necessary. A non-rotating pipe float can be used while the concrete is still plastic, to remove minor irregularities and score marks. Only one pass of the pipe float is allowed. If there is concrete slurry or fluid paste on the surface that runs over the edge of the pavement, immediately stop the paving operation and modify the equipment, mixture, or operation to prevent formation of such slurry. Immediately remove any slurry which runs down the vertical edges by hand, using stiff brushes or scrapers. Slurry, concrete or concrete mortar is not allowed to build up along the edges of the pavement to compensate for excessive edge slump, either while the concrete is plastic or after it hardens.

3.6.3 Surface Correction and Testing

After all other finishing is completed but while the concrete is still plastic, eliminate minor irregularities and score marks in the pavement surface by means of cutting straightedges. Provide cutting straightedges

with a minimum length of 12 feet that are operated from the sides of the pavement or from bridges. Provide cutting straightedges operated from the side of the pavement equipped with a handle 3 feet longer than one-half the width of the pavement. Test the surface for trueness with a straightedge held in successive positions parallel and at right angles to the center line of the pavement, and cover the whole area to detect variations. Advance the straightedge along the pavement in successive stages of not more than one-half the length of the straightedge. Immediately fill depressions with freshly mixed concrete, strike off, consolidate with an internal vibrator, and refinish. Strike off projections above the required elevation and refinish. Continue the straightedge testing and finishing until the entire surface of the concrete is free from observable departure from the straightedge and conforms to the surface requirements specified in paragraph SURFACE SMOOTHNESS. This straightedging is not allowed to be used as a replacement for the straightedge testing of paragraph SURFACE SMOOTHNESS. Use long-handled, flat bull floats very sparingly and only as necessary to correct minor, scattered surface defects. If frequent use of bull floats is necessary, stop the paving operation and adjust the equipment, mixture or procedures to eliminate the surface defects. Keep finishing with hand floats and trowels to the absolute minimum necessary. Take extreme care to prevent overfinishing joints and edges. Produce the surface finish of the pavement essentially by the finishing machine and not by subsequent hand finishing operations. All hand finishing operations are subject to approval.

3.6.4 Hand Finishing

Use hand finishing operations only as specified below. Provide a work bridge to be used as necessary for consolidation and placement operations to avoid standing in concrete.

3.6.4.1 Equipment and Template

In addition to approved mechanical internal vibrators for consolidating the concrete, provide a strike-off and tamping template and a longitudinal float for hand finishing. Provide a template at least 1 foot longer than the width of pavement being finished, of an approved design, and sufficiently rigid to retain its shape, that is constructed of metal or other suitable material shod with metal. Provide a longitudinal float at least 10 feet long, of approved design, that is rigid and substantially braced to maintain a plane surface on the bottom. Grate tampers (jitterbugs) are not allowed.

3.6.4.2 Finishing and Floating

As soon as the plastic concrete is placed and consolidated, strike off the concrete and screed to the cross section and to such elevation above grade that when consolidated and finished, the surface of the pavement is at the required elevation. Immediately following the final tamping of the surface, float the pavement longitudinally from bridges resting on the side forms and spanning but not touching the concrete. Do not advance the floating operation more than half the length of the float and continue over the new and previously floated surfaces.

3.6.5 Texturing

Before the surface sheen has disappeared and before the concrete hardens or curing compound is applied, texture the surface of the pavement as

described herein. After the curing period is complete, thoroughly power broom all textured surfaces to remove all debris.

3.6.5.1 Burlap Drag Surface

Apply surface texture by dragging the surface of the pavement, in the direction of the concrete placement, with an approved burlap drag. Operate the drag with the fabric moist and maintain the fabric clean. Change as required to keep clean. Perform the dragging so as to produce a uniform finished surface having a fine sandy texture without disfiguring marks.

3.6.6 Edging

Before texturing has been completed, carefully finish the edge of the slabs along the forms, along the edges of slipformed lanes, and at the joints with an edging tool to form a smooth rounded surface of 1/8 inch radius. Eliminate tool marks and provide edges that are smooth and true to line. Water is not allowed to be added to the surface during edging. Take extreme care to prevent overworking the concrete.

3.6.7 Pavement Penetrations

Construct recesses for the tie-down anchors, lighting fixtures, and other outlets in the pavement to conform to the details and dimensions shown. Carefully finish the concrete in these areas to provide a surface of the same texture as the surrounding area that is within the requirements for plan grade and surface smoothness.

3.7 CURING

3.7.1 Protection of Concrete

Continuously protect concrete against loss of moisture and rapid temperature changes for at least 7 days from the completion of finishing operations. Have all equipment needed for adequate curing and protection of the concrete on hand and ready for use before actual concrete placement begins. If any selected method of curing does not afford the proper curing and protection against concrete cracking, remove or replace the damaged pavement, and provide another method of curing as directed. Accomplish curing by one of the following methods.

3.7.2 Membrane Curing

Apply a uniform coating of white-pigmented, membrane-forming, curing compound to the entire exposed surface of the concrete as soon as the free water has disappeared from the surface after finishing. Apply immediately along the formed edge faces after the forms are removed. Do not allow the concrete to dry before the application of the membrane. If any drying has occurred, moisten the surface of the concrete with a fine spray of water, and apply the curing compound as soon as the free water disappears. Apply the curing compound to the finished surfaces by means of an approved automatic spraying machine. Apply the curing compound with an overlapping coverage that provides a two-coat application at a coverage of 400 square feet per gallon, plus or minus 5.0 percent for each coat. A one-coat application is allowed provided it is applied in a uniform application and coverage of 200 square feet per gallon, plus or minus 5.0 percent is obtained. The application of curing compound by hand-operated, mechanical powered pressure sprayers is permitted only on odd widths or shapes of

slabs and on concrete surfaces exposed by the removal of forms. When the application is made by hand-operated sprayers, apply a second coat in a direction approximately at right angles to the direction of the first coat. If pinholes, abrasions, or other discontinuities exist, apply an additional coat to the affected areas within 30 minutes. Respray curing compound to concrete surfaces that are subjected to heavy rainfall within 3 hours after the curing compound has been applied. Within the curing period, immediately respray areas where the curing compound is damaged by subsequent construction operations. During the entire curing period, adequately protect membrane-cured concrete surfaces from pedestrian and vehicular traffic, except as required for joint-sawing operations and surface tests, and from any other possible damage to the continuity of the membrane.

3.7.3 Moist Curing

Maintain concrete to be moist-cured continuously wet for the entire curing period, or until curing compound is applied, commencing immediately after finishing. If forms are removed before the end of the curing period, provide curing on unformed surfaces, using suitable materials. Cure surfaces by ponding, by continuous sprinkling, by continuously saturated burlap or cotton mats, or by continuously saturated plastic coated burlap. Provide burlap and mats that are clean and free from any contamination and completely saturated before being placed on the concrete. Lap sheets to provide full coverage. Provide an approved system to provide continuous moist curing 24 hours per day and such that the entire surface is wet.

3.8 JOINTS

3.8.1 General Requirements for Joints

Construct joints that conform to the locations and details indicated and are perpendicular to the finished grade of the pavement. Provide joints that are straight and continuous from edge to edge or end to end of the pavement with no abrupt offset and no gradual deviation greater than 1/2 inch. Where any joint fails to meet these tolerances, remove and replace the slabs adjacent to the joint at no additional cost to the Government. Changes from the jointing pattern shown on the drawings are not allowed without written approval. Seal joints immediately following curing of the concrete or as soon thereafter as weather conditions permit as specified in Section 32 01 19.61 SEALING OF JOINTS IN RIGID PAVEMENT.

3.8.2 Longitudinal Construction Joints

Install dowels in the longitudinal construction joints, or thicken the edges as indicated. Install dowels as specified above. After the end of the curing period, saw longitudinal construction joints to provide a reservoir at the top for sealant conforming to the details and dimensions indicated.

3.8.3 Transverse Construction Joints

Install transverse construction joints at the end of each day's placing operations and at any other points within a paving lane when concrete placement is interrupted for 30 minutes or longer. Provide transverse construction joints by utilizing headers or by paving through the joint, then full-depth saw cutting the excess concrete. Construct pavement with the paver as close to the header as possible, with the paver run out

completely past the header. Provide transverse construction joints at a planned transverse joint constructed as shown or, if not shown otherwise, dowelled in accordance with paragraph DOWELS INSTALLED IN HARDENED CONCRETE, or paragraph FIXED FORM PAVING above.

3.8.4 Expansion Joints

Provide expansion joints where indicated, and about any structures and features that project through or into the pavement, using joint filler of the type, thickness, and width indicated, and installed to form a complete, uniform separation between the structure and the pavement or between two pavements. Attach the filler to the original concrete placement with adhesive and mechanical fasteners and extending to the full slab depth. Tightly fit adjacent sections of filler together, with the filler extending across the full width of the paving lane or other complete distance in order to prevent entrance of concrete into the expansion space. Finish edges of the concrete at the joint face with an edger with a radius of 1/8 inch. After placement and curing of the adjacent slab, sawcut the sealant reservoir depth from the filler.

3.8.5 Slip Joints

Install slip joints where indicated using the specified materials. Attach preformed joint filler material to the face of the original concrete placement with adhesive and mechanical fasteners. Sawcut a 3/4 inch deep reservoir for joint sealant at the top of the joint. Finish edges of the joint face with an edger with a radius of 1/8 inch.

3.8.6 Contraction Joints

Construct transverse and longitudinal contraction joints by an initial sawcut in the concrete with a 1/8 inch blade to the indicated depth. During sawing of joints, and again 24 hours later, inspect all exposed lane edges for development of cracks below the saw cut, and immediately report results. If there are more than six consecutive uncracked joints after 48 hours, saw succeeding joints 25 percent deeper than originally indicated at no additional cost to the Government. Vary the time of initial sawing depending on existing and anticipated weather conditions to prevent uncontrolled cracking of the pavement. Commence sawing of the joints as soon as the concrete has hardened sufficiently to permit cutting the concrete without chipping, spalling, or tearing. Inspect the sawed faces of joints for undercutting or washing of the concrete due to the early sawing, and delay sawing if undercutting is sufficiently deep to cause structural weakness or excessive roughness in the joint. Continue the sawing operation as required during both day and night regardless of weather conditions. Saw the joints in the sequence of the concrete placement. Provide adequate lighting for night work. Illumination using vehicle headlights is not permitted. Provide a chalk line or other suitable guide to mark the alignment of the joint. Before sawing a joint, examine the concrete closely for cracks, and do not saw the joint if a crack has occurred near the planned joint location. Discontinue sawing if a crack develops ahead of the saw cut. Immediately after the joint is sawed, thoroughly flush the saw cut and adjacent concrete surface with water and vacuum until all waste from sawing is removed from the joint and adjacent concrete surface. Properly protect the concrete from damage and cure at sawed joints. Tightly seal the top of the joint opening and the joint groove at exposed edges with cord backer rod before the concrete in the region of the joint is resprayed with curing compound and maintain until removed immediately before sawing the joint sealant reservoir.

Respray the surface with curing compound as soon as free water disappears. Seal the exposed saw cuts on the vertical faces of pilot lanes with bituminous mastic or masking tape. After expiration of the curing period, widen the upper portion of the groove by sawing with ganged diamond saw blades to the width and depth indicated for the joint sealer. Center the reservoir over the initial sawcut.

3.8.7 Thickened Edge Joints

Construct thickened edge joints as indicated on the drawings. Grade the underlying material in the transition area as shown and meet the requirements for smoothness and compaction specified for all other areas of the underlying material.

3.9 REPAIR, REMOVAL AND REPLACEMENT OF NEWLY CONSTRUCTED SLABS

3.9.1 General Criteria

Repair or remove and replace new pavement slabs as specified at no cost to the Government. Removal of partial slabs is not permitted. Prior to any repairs, submit a Repair Recommendations Plan detailing areas exceeding the specified limits as well as repair recommendations required to bring these areas within specified tolerances.

3.9.2 Repair of Free Edge Lane Vertical Faces

Repair excessive edge slump and joint face deformation while concrete is in a plastic state by approved methods using forms in accordance with paragraph Forms for Fixed-Form Paving.

3.9.3 Slabs with Cracks

The Government may require cores to be taken over cracks to determine depth of cracking. Drill cores with a minimum diameter of 6 inches and backfill with an approved concrete mixture. Perform drilling of cores and filling of holes at no expense to the Government. Clean cracks that do not exceed 2 inches in depth; then pressure inject full depth with epoxy resin, Type IV, Grade 1. Remove and replace slabs containing cracks deeper than 2 inches.

3.9.4 Removal and Replacement of Full Slabs

Remove new or existing slabs damaged during construction that contain more than 15.0 percent of each longitudinal or transverse joint edge spalled. Where it is necessary to remove full slabs, remove in accordance with paragraph Removal Of Existing Pavement Slab below. Remove and replace full depth, by full width of the slab, and extend to each original joint. Compact and shape the underlying material as specified in the appropriate section of these specifications, clean the surfaces of all four joint faces of all loose material and contaminants, and coat with a double application of membrane forming curing compound as a bond breaker and to protect concrete that has not been cured for at least 7 days. Install dowels of the size and spacing as specified for other joints in similar pavement by epoxy grouting them into holes drilled into the existing concrete using procedures as specified in paragraph PLACING DOWELS above. Provide dowels for all four edges of the new slab. Cut off original damaged dowels flush with the joint face. Lightly oil or grease protruding portions of new dowels. Place concrete as specified for original construction. Take care to prevent any curing compound from

contacting dowels. Prepare and seal the resulting joints around the new slab as specified for original construction.

3.9.5 Repairing Spalls Along Joints

Repair spalls along joints to be sealed to a depth to restore the full joint-face support prior to placing adjacent pavement. Where directed, repair spalls along joints of new slabs, along edges of adjacent existing concrete, and along parallel cracks by first making a vertical saw cut at least 3 inches outside the spalled area and to a depth of at least 2 inches. Provide saw cuts consisting of straight lines forming rectangular areas without sawing beyond the intersecting saw cut. Chip out the concrete between the saw cut and the joint, or crack, to remove all unsound concrete and into at least 1/2 inch of visually sound concrete. Thoroughly clean the cavity thus formed with high pressure water jets supplemented with oil-free compressed air to remove all loose material. Immediately before filling the cavity, apply a prime coat to the dry cleaned surface of all sides and bottom of the cavity, except any joint face. Apply the prime coat in a thin coating and scrub into the surface with a stiff-bristle brush. Provide prime coat for Portland cement repairs consisting of a neat cement grout and for epoxy resin repairs consisting of epoxy resin, Type III, Grade 1. Fill the prepared cavity with material identified in Table 15 based on the cavity volume.

TABLE 15	
SPALL REPAIRS	
Volume of Prepared Cavity After Removal Operations	Material
less than 0.03 cubic foot	epoxy resin mortar or epoxy resin or latex modified mortar
0.03 cubic foot and 1/3 cubic foot	Portland cement mortar
more than 1/3 cubic foot	Portland cement concrete or latex modified mortar

Provide Portland cement concretes and mortars that consist of very low slump mixtures, 1/2 inch slump or less, proportioned, mixed, placed, consolidated by tamping, and cured, all as directed. Provide epoxy resin mortars made with Type III, Grade 1, epoxy resin, using proportions and mixing and placing procedures as recommended by the manufacturer and approved. Proprietary patching materials may be used, subject to Government approval. Place the epoxy resin materials in the cavity in layers with a maximum thickness of 2 inches. Provide adequate time between placement of additional layers such that the temperature of the epoxy resin material does not exceed 140 degrees F at any time during hardening. Provide mechanical vibrators and hand tampers to consolidate the concrete or mortar. Remove any repair material on the surrounding surfaces of the existing concrete before it hardens. Where the spalled area abuts a joint, provide an insert or other bond-breaking medium to prevent bond at the joint face. For existing joints, seal the bottom contraction crack with backer rod to prevent intrusion of primer or mortar. Saw a reservoir for the joint sealant to the dimensions required for other joints. Thoroughly clean the reservoir and then seal with the sealer specified for the joints. In lieu of sawing, spalls and popouts,

less than 6 inches in maximum dimension and not adjacent to a joint, may be prepared by drilling a core 2 inches in diameter greater than the size of the defect, centered over the defect, and 2 inches deep or 1/2 inch into sound concrete, whichever is greater. Repair the core hole as specified above for other spalls.

3.9.6 Weak Surfaces

Weak surfaces are defined as mortar-rich, rain-damaged, uncured, or containing exposed voids or deleterious materials. Rain damaged pavement is pavement with coarse aggregate exposed at the surface. Cores evaluated by a qualified petrographer to contain carbonation to a depth greater than 1/8 inch or Mohs hardness of less than 2, when tested in accordance with ASTM C1895, are also considered rain damaged. A mortar-rich surface is defined as pavement deficient in plus 4.75 mm U.S. No. 4 sieve size aggregate. Diamond grind slabs containing weak surfaces less than 1/4 inch thick to remove the weak surface. Diamond grind in accordance with paragraph Diamond Grinding Of PCC Surfaces. All diamond ground areas are required to meet the thickness, smoothness and plan grade criteria specified in PART 1 GENERAL. Remove and replace slabs containing weak surfaces greater than 1/4 inch thick.

3.9.7 Repair of Pilot Lane Vertical Faces

Repair excessive edge slump and joint face deformation while concrete is in a plastic state by approved methods.

3.10 EXISTING CONCRETE PAVEMENT REMOVAL AND REPAIR

Demolition of existing operational pavement is not allowed prior to approval of the Proportioning Studies. Remove existing concrete pavement at locations indicated on the drawings. Prior to commencing pavement removal operations, inventory the pavement distresses (cracks, spalls, and corner breaks) along the pavement edge to remain. After pavement removal, survey the remaining edge again to quantify any damage caused by removal operations. Perform both surveys in the presence of the Government. Perform repairs as indicated and as specified herein. Carefully control all operations to prevent damage to the concrete pavement and to the underlying material to remain in place. Perform all saw cuts perpendicular to the slab surface, forming rectangular areas. Perform all existing concrete pavement repairs prior to paving adjacent lanes.

3.10.1 Removal of Existing Pavement Slab

When existing concrete pavement is to be removed and adjacent concrete is to be left in place, perform the first full depth saw cut on the joint between the removal area and adjoining pavement to stay in place with a standard diamond-type concrete saw. Next, perform a full depth saw cut parallel to the joint that is at least 24 inches from the joint and at least 6 inches from the end of any dowels with a wheel saw as specified in paragraph SAWING EQUIPMENT. Remove all pavement beyond this last saw cut in accordance with the approved demolition work plan. Remove all pavement between this last saw cut and the joint line by carefully pulling pieces and blocks away from the joint face with suitable equipment and then picking them up for removal. In lieu of this method, this strip of concrete may be carefully broken up and removed using hand-held jackhammers, 30 lb or less, or other approved light-duty equipment which does not cause stress to propagate across the joint saw cut and cause distress in the pavement which is to remain in place. In lieu of the

above specified removal method, the slab may be sawcut full depth to divide it into several pieces and each piece lifted out and removed. Use suitable equipment to provide a truly vertical lift, and safe lifting devices used for attachment to the slab.

3.10.2 Edge Repair

Protect the edge of existing concrete pavement against which new pavement abuts from damage at all times. Remove and replace slabs which are damaged during construction as directed at no cost to the Government. Repair of previously existing damaged areas is considered a subsidiary part of concrete pavement construction. Saw off all exposed keys and keyways full depth.

3.10.2.1 Spall Repair

Repair spalls caused by construction activities if less than 15.0 percent of any slab's edge. Provide repair materials and procedures as previously specified in paragraph, Repairing Spalls Along Joints. Remove and replace full slabs if spalls exceed 15.0 percent of any slab's edge as specified in paragraph, Removal and Replacement of Full Slabs.

3.10.2.2 Underbreak and Underlying Material

Repair all underbreak by removal and replacement of the damaged slabs in accordance with paragraph REMOVAL AND REPLACEMENT OF FULL SLABS above. Protect the underlying material adjacent to the edge of and under the existing pavement which is to remain from damage or disturbance during removal operations and until placement of new concrete, and shape as directed. Maintain sufficient underlying material in place outside the joint line to completely prevent disturbance of material under the pavement which is to remain in place. Remove and replace any slab with underlying material that is disturbed or loses its compaction.

3.11 PAVEMENT PROTECTION

Exclude traffic from the new pavement by erecting and maintaining barricades and signs until the concrete is at least 14 days old, or for a longer period if so directed. As a construction expedient in paving intermediate lanes between newly paved pilot lanes, operation of the hauling and paving equipment is permitted on the new pavement after the pavement has been cured for 7 days, the joints have been sealed or otherwise protected, the concrete has attained a minimum field cured flexural beam strength of 550 psi and approved means are provided to prevent damage to the slab edge. Fabricate and field cure specimens in accordance with ASTM C31/C31M. Continuously maintain all new and existing pavement carrying construction traffic or equipment completely clean, and clean up spillage of concrete or other materials immediately upon occurrence. Take special care in areas where traffic uses or crosses active airfield pavement. Power broom other existing pavements at least daily when traffic operates. For fill-in lanes, provide equipment that does not damage or spall the edges or joints of the previously constructed pavement. Protect the pavement against all damage prior to final acceptance of the work by the Government. Placement of aggregates, rubble, or other similar construction materials on airfield pavements is not allowed.

3.12 TESTING AND INSPECTION FOR CONTRACTOR QUALITY CONTROL DURING CONSTRUCTION

3.12.1 Testing and Inspection by Contractor

During construction, perform sampling and testing of aggregates, cementitious materials (cement, slag cement, and pozzolan), and concrete to determine compliance with the specifications. Provide facilities and labor for procurement of representative test samples. Furnish sampling platforms and belt templates to obtain representative samples of aggregates from charging belts at the concrete plant. Obtain samples of concrete at the point of delivery to the paver. Testing by the Government in no way relieves the specified testing requirements. Perform the inspection and tests described below and based upon the results of these inspections and tests, take the action required and submit reports as required. Perform this testing regardless of any other testing performed by the Government, either for pay adjustment purposes or for any other reason. Include stationing for all sampling and testing.

3.12.2 Testing and Inspection Requirements

Perform CQC sampling, testing, inspection and reporting in accordance with the following Table. Retest aggregate sources and stockpiles in accordance with Table 16 if not used within the previous 3 months.

TABLE 16			
TESTING AND INSPECTION REQUIREMENTS			
Frequency	Test Method	Control Limit	Corrective Action
<u>Fine Aggregate Gradation and Fineness Modulus</u>			
2 per lot	ASTM C136/C136M sample at belt	9 of 10 tests vary less than 0.15 from average	Retest, resolve, retest
		Outside limits on any sieve	Retest
		2nd gradation failure	Stop, resolve, retest
1 per 10 gradations	ASTM C117	Outside limits on any sieve	Retest
		2nd gradation failure	Stop, repair, retest
<u>Coarse Aggregate Gradation (each aggregate size)</u>			

TABLE 16			
TESTING AND INSPECTION REQUIREMENTS			
Frequency	Test Method	Control Limit	Corrective Action
2 per lot	ASTM C136/C136M sample at belt	Outside limits on any sieve	Retest
		2nd gradation failure	report to COR, correct
		2 consecutive averages of 5 tests outside limits	report to COR, stop ops, repair, retest
1 per 10 gradations	ASTM C117	Outside limits on any sieve	Retest
		2nd gradation failure	report to COR, correct
		2 consecutive averages of 5 tests outside limits	report to COR, stop ops, repair, reverify all operations
<u>Workability Factor and Coarseness Factor Computation</u>			
Same as C.A. and F.A.	see paragraph AGGREGATES	Use individual C.A. and F.A. gradations. Combine using batch ticket percentages (average of aggregate percentages from 3 before and 3 after sampling). Tolerances: plus or minus 3 points on WF; plus or minus 5 points on CF from approved adjusted mix design values; only the portion of the tolerance box within the parallelogram is available for use	Check batching tolerances, recalibrate scales
		2 consecutive averages of 5 tests outside limits	Stop production paving, report to COR, and revise materials and operations to be in compliance prior to restarting production paving
<u>Aggregate Deleterious, Quality, and ASR Tests</u>			

TABLE 16			
TESTING AND INSPECTION REQUIREMENTS			
Frequency	Test Method	Control Limit	Corrective Action
Every 30 days of concrete production	see paragraph AGGREGATES		Stop production, retest, replace aggregate. Increase testing interval to 90 days if previous 2 tests pass
<u>Plant - Scales, Weighing Accuracy</u>			
Monthly	NRMCA QC 3		Stop plant ops, repair, recalibrate
<u>Plant - Batching and Recording Accuracy</u>			
Weekly	Record/Report	Record required/recorded/actual batch mass	Stop plant ops, repair, recalibrate
<u>Plant - Batch Plant Control</u>			
Every lot	Record/Report		Record type and amount of each material per lot
<u>Plant - Mixer Uniformity - Stationary Mixers</u>			
Every 4 months during paving	COE CRD-C 55	After initial approval, use abbreviated method	Increase mixing time, change batching sequence, reduce batch size to bring into compliance. Retest
<u>Plant - Mixer Uniformity - Truck Mixers</u>			
Every 4 months during paving	ASTM C94/C94M	Random selection of truck.	Increase mixing time, change batching sequence, reduce batch size to bring into compliance. Retest
<u>Concrete Mixture - Air Content</u>			

TABLE 16			
TESTING AND INSPECTION REQUIREMENTS			
Frequency	Test Method	Control Limit	Corrective Action
When test specimens prepared plus 2 random per lot	ASTM C231/C231M sample at point of discharge within the paving lane	Individual test control chart: Warning plus or minus 1.0	Adjust AEA, retest
		Individual test control chart: Action plus or minus 1.5	Halt operations, repair, retest
		Range between 2 consecutive tests: Warning plus 2.0	Recalibrate AEA dispenser
		Range between 2 consecutive tests: Action plus 3.0	Halt operations, repair, retest
<u>Concrete Mixture - Unit Weight and Yield</u>			
Same as Air Content	ASTM C138/C138M sample at point of discharge within the paving lane	Individual test basis: Warning Yield minus 0 or plus 1 percent	Check batching tolerances
		Individual test basis: Action Yield minus 0 or plus 5 percent	Halt operations
<u>Concrete Mixture - Slump</u>			
When test specimens prepared plus 4 random per lot	ASTM C143/C143M sample at point of discharge within the paving lane	Individual test control chart: Upper Warning slipform minus 1/2 inch below max fixed form 1.5 inches hand placement 2.5 inches	Adjust batch masses within max W/C ratio
		Individual test control chart: Upper Action at maximum allowable slump	Stop operations, adjust, retest
		Range between each consecutive test: 1-1/2 inches	Stop operations, repair, retest
<u>Concrete Mixture - Temperature</u>			

TABLE 16			
TESTING AND INSPECTION REQUIREMENTS			
Frequency	Test Method	Control Limit	Corrective Action
When test specimens prepared	ASTM C1064/C1064M sample at point of discharge within the paving lane	See paragraph WEATHER LIMITATIONS	
<u>Concrete Mixture - Strength</u>			
8 per lot	ASTM C31/C31M sample at point of discharge within the paving lane	See paragraph CONCRETE STRENGTH TESTING for CQC Perform fabrication of strength specimens and initial cure outside the paving lane and within 1,000 feet of the sampling point.	
<u>Paving - Inspection Before Paving</u>			
Prior to each paving operation	Report	Inspect underlying materials, construction joint faces, forms, reinforcing, dowels, and embedded items	
<u>Paving - Inspection During Paving</u>			
During paving operation		Monitor and control paving operation, including placement, consolidation, finishing, texturing, curing, and joint sawing.	
<u>Paving - Vibrators</u>			
Weekly during paving	COE CRD-C 521	Test frequency (in concrete), and amplitude (in air), average measurement at tip and head.	Repair or replace defective vibrators.
<u>Moist Curing</u>			
2 per lot, min 4 per day	Visual		Repair defects, extend curing by 1 day
<u>Membrane Compound Curing</u>			

TABLE 16			
TESTING AND INSPECTION REQUIREMENTS			
Frequency	Test Method	Control Limit	Corrective Action
Daily	Visual	Calculate coverage based on quantity/area	Respray areas where coverage defective. Recalibrate equipment
<u>Cold Weather Protection</u>			
Once per day	Visual		Repair defects, report conditions to COR

3.12.3 Control Charts

Maintain linear control charts for fine and coarse aggregate gradation, combined gradation coarseness factor/workability factor, slump, air content, unit weight, yield, and 7- and 14-day flexural strengths.

Post the control charts as directed and maintain current at all times. Identify the following on the control charts: the project number, the test parameter being plotted, the individual sample numbers, the Warning and Action Limits listed in Table 16 applicable to the test parameter being plotted, and the test results. Use the control charts as part of the process control system for identifying trends so that potential problems can be corrected before they occur. Make decisions concerning mix modifications based on analysis of the results provided in the control charts.

3.12.4 Concrete Strength Testing for CQC

Perform Contractor Quality Control operations for concrete strength consisting of the following steps:

- a. Take samples for strength tests at the paving site. Fabricate and cure test beams in accordance with ASTM C31/C31M; test them in accordance with ASTM C78/C78M.
- b. Fabricate and cure 2 test beams per subplot from the same batch or truckload and at the same time acceptance beams are fabricated and test them for flexural strength at 7-day age.
- c. Average all 8 flexural tests per lot. Convert this average 7-day flexural strength per lot to equivalent 90-day flexural strength using the Correlation Ratio determined during mixture proportioning studies.
- d. Compare the equivalent 90-day flexural strength from the conversion to the required average CQC flexural strength, Ra.
- e. If the equivalent average 90-day strength for the lot is below the required average CQC flexural strength, Ra, by 69 psi flexural strength or more, at any time, adjust the mixture to increase the strength, as approved.
- f. Maintain up-to-date control charts for strength, showing the 7-day CQC flexural strength, the Ratio of the 14-day flexural strength to the

90-day flexural strength (from acceptance tests), and the 90-day flexural strength (from acceptance tests) of each of these for each lot.

3.12.5 Reports

Report all results of tests or inspections conducted as they are completed and in writing daily. Post updated control charts and identify accepted paving lots on the detailed paving sequence paving plan covering the entire period from the start of paving through the current week. These requirements do not relieve the obligation to report failures immediately as required in preceding paragraphs and Section 01 45 00 QUALITY CONTROL. Confirm reports of failures and the corrective action taken in writing in the daily Quality Control reports and within each respective Paving Lot Report. Compile, reduce, analyze and compute pay adjustment factors for all associated test data collected on each paving lot.

Submit complete and comprehensive Paving Lot Reports for the test section and production paving within 16 days after the completion of the placement. Do not place an adjacent or contiguous lane/lot prior to providing required pavement data identified in items a. - y. conforming to the acceptance criteria. Payment will not be made until all required data identified in items a. - y. has been submitted and reviewed by the government. Organize each Paving Lot Report by the following specific items. The list below is not all inclusive. Add tests and inspections as appropriate for each specific paving lot constructed.

Table Summary of payment adjustment factors and pass/fail factors Detailed Placement Plan, labeling lots/sublots with stationing. Identify core locations, and testing locations.

Provide narrative addressing the following at a minimum:

- a. Protective Measures: Rain, Cold, Hot and/or windy on-site conditions including evaporation rates, high/low ambient temperature. Post-Production protection and traffic control.
- b. Success, failures, and issues encountered during all operations associated with the placement to include, but not limited to, batching, transporting, paving, texturing and curing. Include any process control changes that were necessary to meet specified tolerances.
- c. Stockpile Management before and during placement.
- d. Initial saw cutting operation to include start and finish times (early entry or wet diamond, flushing and vacuuming, backer rod installation and reapplication of curing compound).
- e. Finishing operations (cutting straight-edge, automatic longitudinal float, edging tool, minimal hand work and excess paste).
- f. Texturing operations to include start and finish times.
- g. Curing operations to include start and finish times.
- h. Environmental conditions of initial cure facility to include location and temperatures.
- i. Planned correction(s) or correction(s) completed

j. Dowel installation

Provide required inspection documentation for the following at a minimum:

k. Batch Plant, Equipment, and Curing Equipment Verification

l. Dowel Baskets, forms, reinforcing, embeds and block-outs

m. Summary of recent underlying material test results showing compliance. Include information such as submittal numbers or date of daily report(s) where the detailed testing data is located.

Quality Control Testing

n. PCC Plastic Mixture Properties (temperature, air content, slump, unit weight)

o. Aggregate gradation test results and CF-WF plot

p. Control Charts

q. Joint Crack Tracking and Record

Acceptance Testing (before and after corrections)

r. Surface Smoothness test results (straightedge and profilograph) in both longitudinal and transverse directions.

s. Edge Slump test results(identify excessive, lost and rebuilt edge(s)).

t. Joint Face Deformation test results.

u. Plan Grade: table providing x, y, and elevation values versus design values signed by licensed surveyor.

v. Strength: beam/cylinder strength results (with updated correlation ratios and control chart).

w. Cores: Locations/Stationing of cores shown on Placement Plan, thickness measurements, photos and evaluation of cores.

x. Dowel holes, and dowel alignment

y. Legible copies of batch tickets. Tickets should include all required data, time received, and time discharge completed.

-- End of Section --

SECTION 32 16 19

CONCRETE CURBS, GUTTERS AND SIDEWALKS
05/18

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
(AASHTO)

AASHTO M 182 (2005; R 2017) Standard Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats

ASTM INTERNATIONAL (ASTM)

ASTM A615/A615M (2022) Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

ASTM A1064/A1064M (2022) Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

ASTM C31/C31M (2024) Standard Practice for Making and Curing Concrete Test Specimens in the Field

ASTM C94/C94M (2023) Standard Specification for Ready-Mixed Concrete

ASTM C143/C143M (2020) Standard Test Method for Slump of Hydraulic-Cement Concrete

ASTM C171 (2020) Standard Specification for Sheet Materials for Curing Concrete

ASTM C172/C172M (2017) Standard Practice for Sampling Freshly Mixed Concrete

ASTM C173/C173M (2024) Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

ASTM C231/C231M (2024) Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

ASTM C309 (2019) Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete

ASTM C920	(2018) Standard Specification for Elastomeric Joint Sealants
ASTM D1751	(2018) Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
ASTM D1752	(2018) Standard Specification for Preformed Sponge Rubber, Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction
ASTM D5893/D5893M	(2016) Standard Specification for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Concrete

SD-06 Test Reports

Field Quality Control

1.3 EQUIPMENT, TOOLS, AND MACHINES

1.3.1 General Requirements

Plant, equipment, machines, and tools used in the work will be subject to approval and must be maintained in a satisfactory working condition at all times. Use equipment capable of producing the required working product, meeting grade controls, thickness control and smoothness requirements as specified. Discontinue using equipment that produces unsatisfactory results. Allow the Contracting Officer access at all times to the plant and equipment to ensure proper operation and compliance with specifications.

1.3.2 Slip Form Equipment

Slip form paver or curb forming machines, will be approved based on trial use on the job and must be self-propelled, automatically controlled, crawler mounted, and capable of spreading, consolidating, and shaping the plastic concrete to the desired cross section in one pass.

1.4 ENVIRONMENTAL REQUIREMENTS

1.4.1 Placing During Cold Weather

Do not place concrete when the air temperature reaches 40 degrees F and is falling or is already below that point. Placement may begin when the air temperature reaches 35 degrees F and is rising, or is already above 40 degrees F. Make provisions to protect the concrete from freezing during the specified curing period. If necessary to place concrete when the temperature of the air, aggregates, or water is below 35 degrees F, placement and protection must be approved in writing. Approval will be contingent upon full conformance with the following provisions. Prepare and protect the underlying material so that it is entirely free of frost when the concrete is deposited. Heat mixing water and aggregates as necessary to result in the temperature of the in-place concrete being between 50 and 85 degrees F. Methods and equipment for heating must be approved. Use only aggregates that are free of ice, snow, and frozen lumps before entering the mixer. Provide covering or other means as needed to maintain the concrete at a temperature of at least 50 degrees F for not less than 72 hours after placing, and at a temperature above freezing for the remainder of the curing period.

1.4.2 Placing During Warm Weather

The temperature of the concrete as placed must not exceed 85 degrees F except where an approved retarder is used. Cool the mixing water and aggregates as necessary to maintain a satisfactory placing temperature. The placing temperature must not exceed 95 degrees F at any time.

PART 2 PRODUCTS

2.1 CONCRETE

Provide concrete conforming to the applicable requirements of ASTM C94/C94M except as otherwise specified. Concrete must have a minimum compressive strength of 3500 psi at 28 days. Size of aggregate must not exceed 1-1/2 inches. Submit copies of certified delivery tickets for all concrete used in the construction.

2.1.1 Air Content

Use concrete mixtures that have an air content by volume of concrete of 3 to 6 percent, based on measurements made immediately after discharge from the mixer.

2.1.2 Slump

Use concrete with a slump of 3 inches plus or minus 1 inch for hand placed concrete or 1 inch plus or minus 1/2 inch for slipformed concrete as determined in accordance with ASTM C143/C143M.

2.1.3 Reinforcement Steel

Use reinforcement bars conforming to ASTM A615/A615M. Use wire mesh reinforcement conforming to ASTM A1064/A1064M.

2.2 CONCRETE CURING MATERIALS

2.2.1 Impervious Sheet Materials

Use impervious sheet materials conforming to ASTM C171, type optional, except that polyethylene film, if used, must be white opaque.

2.2.2 Burlap

Use burlap conforming to AASHTO M 182.

2.2.3 White Pigmented Membrane-Forming Curing Compound

Use white pigmented membrane-forming curing compound conforming to ASTM C309, Type 2.

2.3 CONCRETE PROTECTION MATERIALS

Use concrete protection materials consisting of a linseed oil mixture of equal parts, by volume, of linseed oil and either mineral spirits, naphtha, or turpentine. At the option of the Contractor, commercially prepared linseed oil mixtures, formulated specifically for application to concrete to provide protection against the action of deicing chemicals may be used, except that emulsified mixtures are not acceptable.

2.4 JOINT FILLER STRIPS

2.4.1 Contraction Joint Filler for Curb and Gutter

Use hard-pressed fiberboard contraction joint filler for curb and gutter.

2.4.2 Expansion Joint Filler, Premolded

Unless otherwise indicated, use 3/4 inch thick premolded expansion joint filler conforming to ASTM D1751 or ASTM D1752.

2.5 JOINT SEALANTS

Use cold-applied joint sealant conforming to ASTM C920 or ASTM D5893/D5893M.

2.6 FORM WORK

Design and construct form work to ensure that the finished concrete will conform accurately to the indicated dimensions, lines, and elevations, and within the tolerances specified. Use wood or steel forms that are straight and of sufficient strength to resist springing during depositing and consolidating concrete.

2.6.1 Wood Forms

Use forms that are surfaced plank 2 inches nominal thickness, straight and free from warp, twist, loose knots, splits or other defects. Use forms with a nominal length of 10 feet. Radius bends may be formed with 3/4 inch boards, laminated to the required thickness.

2.6.2 Steel Forms

Use channel-formed sections with a flat top surface and welded braces at each end and at not less than two intermediate points. Use forms with

interlocking and self-aligning ends. Provide flexible forms for radius forming, corner forms, form spreaders, and fillers as needed. Use forms with a nominal length of 10 feet and that have a minimum of 3 welded stake pockets per form. Use stake pins consisting of solid steel rods with chamfered heads and pointed tips designed for use with steel forms.

2.6.3 Sidewalk Forms

Use sidewalk forms that are of a height equal to the full depth of the finished sidewalk.

PART 3 EXECUTION

3.1 SUBGRADE PREPARATION

Construct subgrade to the specified grade and cross section prior to concrete placement.

3.1.1 Sidewalk Subgrade

Place and compact the subgrade in accordance with Section 31 00 00 EARTHWORK and Section 32 11 20 Base Course for Rigid Paving and Sidewalk. Test the subgrade for grade and cross section with a template extending the full width of the sidewalk and supported between side forms.

3.1.2 Maintenance of Subgrade

Maintain subgrade in a smooth, compacted condition in conformity with the required section and established grade until the concrete is placed. The subgrade must be in a moist condition when concrete is placed. Prepare and protect subgrade so that it is free from frost when the concrete is deposited.

3.2 FORM SETTING

Set forms to the indicated alignment, grade and dimensions. Hold forms rigidly in place by a minimum of 3 stakes per form placed at intervals not to exceed 4 feet. Use additional stakes and braces at corners, deep sections, and radius bends, as required. Use clamps, spreaders, and braces where required to ensure rigidity in the forms. Remove forms in a manner that will not injure the concrete. Do not use bars or heavy tools against the concrete when removing the forms. Promptly and satisfactorily repair concrete found to be defective after form removal. Clean forms and coat with form oil each time before concrete is placed. Wood forms may, instead, be thoroughly wetted with water before concrete is placed, except that with probable freezing temperatures, oiling is mandatory.

3.2.1 Sidewalks

Set forms for sidewalks with the upper edge true to line and grade with an allowable tolerance of 1/8 inch in any 10-foot long section. After forms are set, grade and alignment must be checked with a 10-foot straightedge. Sidewalks must have a transverse slope as indicated. Unless otherwise indicated, construct sidewalks that are located adjacent to curbs with the low side adjacent to the curb. Do not remove side forms less than 12 hours after finishing has been completed.

3.3 SIDEWALK CONCRETE PLACEMENT AND FINISHING

3.3.1 Formed Sidewalks

Place concrete in the forms in one layer. When consolidated and finished, the sidewalks must be of the thickness indicated. Use a strike-off guided by side forms after concrete has been placed in the forms to bring the surface to proper section to be compacted. Consolidate concrete by tamping and spading or with an approved vibrator. Finish the surface to grade with a strike off.

3.3.2 Concrete Finishing

After straightedging, when most of the water sheen has disappeared, and just before the concrete hardens, finish the surface with a wood or magnesium float or darby to a smooth and uniformly fine granular or sandy texture free of waves, irregularities, or tool marks. Produce a scored surface by brooming with a fiber-bristle brush in a direction transverse to that of the traffic, followed by edging.

3.3.3 Edge and Joint Finishing

Finish all slab edges, including those at formed joints, with an edger having a radius of 1/8 inch. Edge transverse joints before brooming. Eliminate the flat surface left by the surface face of the edger with brooming. Clean and solidly fill corners and edges which have crumbled and areas which lack sufficient mortar for proper finishing with a properly proportioned mortar mixture and then finish.

3.3.4 Surface and Thickness Tolerances

Finished surfaces must not vary more than 5/16 inch from the testing edge of a 10-foot straightedge. Permissible deficiency in section thickness will be up to 1/4 inch.

3.4 SIDEWALK JOINTS

Construct sidewalk joints to divide the surface into rectangular areas. Space transverse contraction joints at a distance equal to the sidewalk width or 5 feet on centers, whichever is less, and continuous across the slab. Construct longitudinal contraction joints along the centerline of all sidewalks 10 feet or more in width. Construct transverse expansion joints at sidewalk returns and opposite expansion joints in adjoining curbs. Where the sidewalk is not in contact with the curb, install transverse expansion joints as indicated. Form expansion joints around structures and features which project through or into the sidewalk pavement, using joint filler of the type, thickness, and width indicated. Expansion joints are not required between sidewalks and curb that abut the sidewalk longitudinally.

3.4.1 Sidewalk Contraction Joints

Form contraction joints in the fresh concrete by cutting a groove in the top portion of the slab to a depth of at least one-fourth of the sidewalk slab thickness. Unless otherwise approved or indicated, either use a jointer to cut the groove or saw a groove in the hardened concrete with a power-driven saw. Construct sawed joints by sawing a groove in the concrete with a 1/8-inch blade. Provide an ample supply of saw blades on the jobsite before concrete placement is started. Provide at least one

standby sawing unit in good working order at the jobsite at all times during the sawing operations.

3.4.2 Sidewalk Expansion Joints

Form expansion joints using 3/4-inch joint filler strips. Joint filler in expansion joints surrounding structures and features within the sidewalk may consist of preformed filler material conforming to ASTM D1752 or building paper. Hold joint filler in place with steel pins or other devices to prevent warping of the filler during floating and finishing. Immediately after finishing operations are completed, round joint edges using an edging tool having a radius of 1/8 inch. Remove any concrete over the joint filler. At the end of the curing period, clean the top of expansion joints and fill with cold-applied joint sealant. Use joint sealant that is gray or stone in color. Thoroughly clean the joint opening before the sealing material is placed. Do not spill sealing material on exposed surfaces of the concrete. Apply joint sealing material only when the concrete at the joint is surface dry and atmospheric and concrete temperatures are above 50 degrees F. Immediately remove any excess material on exposed surfaces of the concrete and clean the concrete surfaces.

3.4.3 Reinforcement Steel Placement

Accurately and securely fasten reinforcement steel in place with suitable supports and ties before the concrete is placed.

3.5 CURING AND PROTECTION

3.5.1 General Requirements

Protect concrete against loss of moisture and rapid temperature changes for at least 7 days from the beginning of the curing operation. Protect unhardened concrete from rain and flowing water. All equipment needed for adequate curing and protection of the concrete must be on hand and ready for use before actual concrete placement begins. Protect concrete as necessary to prevent cracking of the pavement due to temperature changes during the curing period.

3.5.1.1 Mat Method

Cover the entire exposed surface with two or more layers of burlap. Overlap mats at least 6 inches. Thoroughly wet the mat with water prior to placing on concrete surface and keep the mat continuously in a saturated condition and in intimate contact with concrete for not less than 7 days.

3.5.1.2 Impervious Sheeting Method

Wet the entire exposed surface with a fine spray of water and then cover with impervious sheeting material. Lay sheets directly on the concrete surface with the light-colored side up and overlapped 12 inches when a continuous sheet is not used. Use sheeting that is not less than 18-inches wider than the concrete surface to be cured. Secure sheeting using heavy wood planks or a bank of moist earth placed along edges and laps in the sheets. Satisfactorily repair or replace sheets that are torn or otherwise damaged during curing. Sheeting must remain on the concrete surface to be cured for not less than 7 days.

3.5.1.3 Membrane Curing Method

Apply a uniform coating of white-pigmented membrane-curing compound to the entire exposed surface of the concrete as soon after finishing as the free water has disappeared from the finished surface. Coat formed surfaces immediately after the forms are removed and in no case longer than 1 hour after the removal of forms. Do not allow concrete surface to dry before application of the membrane. If drying has occurred, moisten the surface of the concrete with a fine spray of water and apply the curing compound as soon as the free water disappears. Apply curing compound in two coats by hand-operated pressure sprayers at a coverage of approximately 200 square feet/gallon for the total of both coats. Apply the second coat in a direction approximately at right angles to the direction of application of the first coat. The compound must form a uniform, continuous, coherent film that will not check, crack, or peel and must be free from pinholes or other imperfections. If pinholes, abrasion, or other discontinuities exist, apply an additional coat to the affected areas within 30 minutes. Respray concrete surfaces that are subjected to heavy rainfall within 3 hours after the curing compound has been applied by the method and at the coverage specified above. Respray areas where the curing compound is damaged by subsequent construction operations within the curing period. Take precautions necessary to ensure that the concrete is properly cured at sawed joints, and that no curing compound enters the joints. Tightly seal the top of the joint opening and the joint groove at exposed edges before the concrete in the region of the joint is resprayed with curing compound. Use a method used for sealing the joint groove that prevents loss of moisture from the joint during the entire specified curing period. Provide approved standby facilities for curing concrete pavement at a location accessible to the jobsite for use in the event of mechanical failure of the spraying equipment or other conditions that might prevent correct application of the membrane-curing compound at the proper time. Adequately protect concrete surfaces to which membrane-curing compounds have been applied during the entire curing period from pedestrian and vehicular traffic, except as required for joint-sawing operations and surface tests, and from other possible damage to the continuity of the membrane.

3.5.2 Backfilling

After curing, remove debris and backfill, grade, and compact the area adjoining the concrete to conform to the surrounding area in accordance with lines and grades indicated.

3.5.3 Protection

Protect completed concrete from damage until accepted. Repair damaged concrete and clean concrete discolored during construction. Remove and reconstruct concrete that is damaged for the entire length between regularly scheduled joints. Refinishing the damaged portion will not be acceptable. Dispose of removed material as directed.

3.6 FIELD QUALITY CONTROL

Submit copies of all test reports within 24 hours of completion of the test.

3.6.1 General Requirements

Perform the inspection and tests described and meet the specified

requirements for inspection details and frequency of testing. Based upon the results of these inspections and tests, take the action and submit reports as required below, and additional tests to ensure that the requirements of these specifications are met.

3.6.2 Concrete Testing

3.6.2.1 Strength Testing

Take concrete samples in accordance with ASTM C172/C172M not less than once a day nor less than once for every 250 cubic yards of concrete placed. Mold cylinders in accordance with ASTM C31/C31M for strength testing by an approved laboratory. Each strength test result must be the average of 2 test cylinders from the same concrete sample tested at 28 days, unless otherwise specified or approved. Concrete specified on the basis of compressive strength will be considered satisfactory if the averages of all sets of three consecutive strength test results equal or exceed the specified strength, and no individual strength test result falls below the specified strength by more than 500 psi.

3.6.2.2 Air Content

Determine air content in accordance with ASTM C173/C173M or ASTM C231/C231M. Use ASTM C231/C231M with concretes and mortars made with relatively dense natural aggregates. Make two tests for air content on randomly selected batches of each class of concrete placed during each shift. Make additional tests when excessive variation in concrete workability is reported by the placing foreman or the Government inspector. Notify the placing foreman if results are out of tolerance. The placing foreman must take appropriate action to have the air content corrected at the plant. Additional tests for air content will be performed on each truckload of material until such time as the air content is within the tolerance specified.

3.6.2.3 Slump Test

Perform two slump tests on randomly selected batches of each class of concrete for every 250 cubic yards, or fraction thereof, of concrete placed during each shift. Perform additional tests when excessive variation in the workability of the concrete is noted or when excessive crumbling or slumping is noted along the edges of slip-formed concrete.

3.6.3 Thickness Evaluation

Determine the anticipated thickness of the concrete prior to placement by passing a template through the formed section or by measuring the depth of opening of the extrusion template of the curb forming machine. If a slip form paver is used for sidewalk placement, construct the subgrade true to grade prior to concrete placement. The thickness will be determined by measuring each edge of the completed slab.

3.6.4 Surface Evaluation

Provide finished surfaces for each category of the completed work that are uniform in color and free of blemishes and form or tool marks.

3.7 SURFACE DEFICIENCIES AND CORRECTIONS

3.7.1 Thickness Deficiency

When measurements indicate that the completed concrete section is deficient in thickness by more than 1/4 inch the deficient section will be removed, between regularly scheduled joints, and replaced.

3.7.2 High Areas

In areas not meeting surface smoothness and plan grade requirements, reduce high areas either by rubbing the freshly finished concrete with carborundum brick and water when the concrete is less than 36 hours old or by grinding the hardened concrete with an approved surface grinding machine after the concrete is 36 hours old or more. The area corrected by grinding the surface of the hardened concrete must not exceed 5 percent of the area of any integral slab, and the depth of grinding must not exceed 1/4 inch. Remove and replace pavement areas requiring grade or surface smoothness corrections in excess of the limits specified.

3.7.3 Appearance

Exposed surfaces of the finished work will be inspected by the Contracting Officer and deficiencies in appearance will be identified. Remove and replace areas which exhibit excessive cracking, discoloration, form marks, or tool marks or which are otherwise inconsistent with the overall appearances of the work.

-- End of Section --

SECTION 32 17 23

PAVEMENT MARKINGS
08/16, CHG 5: 11/18

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

- | | |
|------------|--|
| ASTM D4061 | (2013) Standard Test Method for Retroreflectance of Horizontal Coatings |
| ASTM D6628 | (2003; R 2015) Standard Specification for Color of Pavement Marking Materials |
| ASTM E1710 | (2011) Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer |
| ASTM E2177 | (2011) Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (RL) of Pavement Markings in a Standard Condition of Wetness |
| ASTM E2302 | (2003; R 2016) Standard Test Method for Measurement of the Luminance Coefficient Under Diffuse Illumination of Pavement Marking Materials Using a Portable Reflectometer |

INTERNATIONAL CONCRETE REPAIR INSTITUTE (ICRI)

- | | |
|------------|--|
| ICRI 03732 | (1997) Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays |
|------------|--|

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

- | | |
|------------------|--|
| SAE AMS-STD-595A | (2017) Colors used in Government Procurement |
|------------------|--|

U.S. FEDERAL HIGHWAY ADMINISTRATION (FHWA)

- | | |
|-------|--|
| MUTCD | (2009; Rev 2012) Manual on Uniform Traffic Control Devices |
|-------|--|

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

- | | |
|--------------|--|
| FS TT-B-1325 | (Rev D; Notice 1; Notice 2 2017) Beads (Glass Spheres) Retro-Reflective (Metric) |
|--------------|--|

FS TT-P-1952

(2015; Rev F; Notice 1) Paint, Traffic and
Airfield Markings, Waterborne

1.2 SUBMITTALS

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Application Equipment List

Exterior Surface Preparation

Safety Data Sheets

Reflective media for airfields

Waterborne Paint

SD-06 Test Reports

Reflective Media for Airfields

Waterborne Paint

SD-07 Certificates

Qualifications

Reflective Media for Airfields

Waterborne Paint

Volatile Organic Compound, (VOC)

SD-08 Manufacturer's Instructions

Waterborne Paint

1.3 QUALITY ASSURANCE

1.3.1 Regulatory Requirements

Submit certificate stating that the proposed pavement marking paint meets the Volatile Organic Compound, (VOC) regulations of the local Air Pollution Control District having jurisdiction over the geographical area in which the project is located. Submit Safety Data Sheets for each product.

1.3.2 Qualifications

Submit documentation certifying that pertinent personnel are qualified for equipment operation and handling of applicable chemicals. The documentation should include experience on five projects of similar size

and scope with references for all personnel.

1.3.3 Qualifications For Airfield Marking Personnel

Submit documentation of qualifications in resume format a minimum of 14 days before pavement marking work is to be performed showing personnel who will be performing the work have experience working on airfields, operating mobile self-powered marking, cleaning, and paint removal equipment and performing these tasks. Include with resume a list of references complete with points of contact and telephone numbers. Provide certification for pavement marking machine operator and Foreman demonstrating experience successfully completing a minimum of two airfield pavement marking projects of similar size and scope. Provide documentation demonstrating personnel have a minimum of three years of experience operating similar equipment and performing the same or similar work in similar environments, similar in size and scope of the planned project. The Contracting Officer reserves the right to require additional proof of competency or to reject proposed personnel.

1.4 DELIVERY AND STORAGE

Deliver paint materials, thermoplastic compound materials, and reflective media in original sealed containers that plainly show the designated name, specification number, batch number, color, date of manufacture, manufacturer's directions, and name of manufacturer.

Provide storage facilities at the job site, only in areas approved by the Contracting Officer, for maintaining materials at temperatures recommended by the manufacturer. Make available paint stored at the project site or segregated at the source for sampling not less than 30 days prior to date of required approval for use to allow sufficient time for testing. Notify the Contracting Officer when paint is available for sampling.

1.5 PROJECT/SITE CONDITIONS

1.5.1 Environmental Requirements

1.5.1.1 Weather Limitations for Application

Apply pavement markings to clean, dry surfaces, and unless otherwise approved, only when the air and pavement surface temperature is at least 5 degrees F above the dew point and the air and pavement temperatures are within the limits recommended by the pavement marking manufacturer. Allow pavement surfaces to dry after water has been used for cleaning or rainfall has occurred prior to striping or marking. Test the pavement surface for moisture before beginning work each day and after cleaning. Do not commence marking until the pavement is sufficiently dry and the pavement condition has been approved by the Contracting Officer. Employ the "plastic wrap method" to test the pavement for moisture as specified in paragraph TESTING FOR MOISTURE.

1.5.1.2 Weather Limitations for Removal of Pavement Markings

Pavement surface must be free of snow, ice, or slush; with a surface temperature of at least 40 degrees F and rising at the beginning of operations, except those involving shot or sand blasting or grinding. Cease operation during thunderstorms, or during rainfall, except for waterblasting and removal of previously applied chemicals. Cease waterblasting where surface water accumulation alters the effectiveness of

material removal.

1.5.2 Traffic Controls

Place warning signs conforming to MUTCD near the beginning of the worksite and well ahead of the worksite for alerting approaching traffic from both directions. Place small markers along newly painted lines or freshly placed raised markers to control traffic and prevent damage to newly painted surfaces or displacement of raised pavement markers. Mark painting equipment with large warning signs indicating slow-moving painting equipment in operation.

When traffic must be rerouted or controlled to accomplish the work, provide necessary warning signs, flag persons, and related equipment for the safe passage of vehicles.

1.5.3 Airfield Traffic Control

Coordinate performance of all work in the controlled zones of the airfield with the Contracting Officer and with the Flight Operations Officer or Airfield Manager and control tower. Neither equipment nor personnel can use any portion of the airfield without permission of these officers unless the associated pavements are closed.

1.5.4 Airfield Radio Communication

No personnel or equipment will be allowed in the controlled zones of the airfield until radio contact has been made with the control tower and permission is granted by the control tower. A radio for this purpose is to be provided by the Contractor as approved by the Contracting Officer. Maintain contact with the control tower at all times during work in vicinity of the airfield. Notify the control tower when work is completed and all personnel, equipment and materials have been removed from all aircraft operating surfaces.

1.5.5 Airfield Emergency Landing and Takeoff

Emergencies take precedence over all operations. Upon notification from the control tower of an emergency landing or imminent takeoff, stop all operations immediately and evacuate all personnel and equipment to an area not utilized for aircraft traffic which is at least 250 feet measured perpendicular to and away from the near edge of the runway unless otherwise authorized by the Contracting Officer. Equipment and chemicals or detergents as well as excess water must be able to be removed from the work area within 3 minutes.

1.5.6 Lighting

When night operations are necessary, provide all necessary lighting and equipment. Direct or shade lighting to prevent interference with aircraft, the air traffic control tower, and other base operations. Provide lighting and related equipment capable of being removed from the runway within 15 minutes of notification of an emergency. Night work must be coordinated with the Flight Operations Manager or Airfield Manager and approved in advance by the Contracting Officer. The Government reserves the right to accept or reject night work on the day following night activities by the Contractor.

PART 2 PRODUCTS

2.1 EQUIPMENT

2.1.1 Surface Preparation and Paint Removal

2.1.1.1 Surface Preparation and Paint Removal Equipment for Airfield Pavements

Submit product data for mechanical paint removal equipment including area of coverage per pass, range of water pressures, and water tank capacity. Mechanical removal equipment includes waterblasting non-chemical systems. Control the equipment used on Portland cement concretes to remove paint accumulations and prevent removal of hardened paste from the concrete. Basic hand tools and the following major types of mechanical equipment are considered acceptable for this project:

a. Waterblasting Equipment

2.1.1.1.1 Waterblasting Equipment

Use mobile waterblasting equipment capable of producing a pressurized stream of water that effectively removes paint from the pavement surface without significantly damaging the pavement. Provide equipment, tools, and machinery which are safe and in good working order at all times.

2.1.2 Application Equipment

Submit application equipment list appropriate for the material(s) to be used. Include manufacturer's descriptive data and certification for the planned use that indicates area of coverage per pass, pressure adjustment range, tank and flow capacities, and all safety precautions required for operating and maintaining the equipment. Provide and maintain machines, tools, and equipment used in the performance of the work in satisfactory operating condition, or remove them from the work site. Provide mobile and maneuverable application equipment to the extent that straight lines can be followed and normal curves can be made in a true arc.

2.1.2.1 Paint Application Equipment

2.1.2.1.1 Hand-Operated, Push-Type Machines

Provide hand-operated push-type applicator machine of a type commonly used for application of water-based paint or two-component, chemically curing paint, thermoplastic, or preformed tape, to pavement surfaces for small marking projects, such as legends and cross-walks, automotive parking areas, or surface painted signs. Provide applicator machine equipped with the necessary tanks and spraying nozzles capable of applying paint uniformly at coverage specified. Hand operated spray guns may be used in areas where push-type machines cannot be used.

2.1.2.1.2 Self-Propelled or Mobile-Drawn Spraying Machines

Provide self-propelled or mobile-drawn spraying machine with suitable arrangements of atomizing nozzles and controls to obtain the specified results. Provide machine having a speed during application capable of applying the stripe widths indicated at the paint coverage rate specified

herein and of even uniform thickness with clear-cut edges.

2.1.2.1.2.1 Airfield Marking

Provide self-propelled or mobile-drawn spraying machine for applying the paint for airfield pavements with an arrangement of atomizing nozzles capable of applying the specified line width in a single pass. Provide paint applicator with paint reservoirs or tanks of sufficient capacity and suitable gages to apply paint in accordance with requirements specified. Equip tanks with suitable mechanical agitators. Equip spray mechanism with quick-action valves conveniently located, and include necessary pressure regulators and gages in full view and reach of the operator. Install paint strainers in paint supply lines to ensure freedom from residue and foreign matter that may cause malfunction of the spray guns. The paint applicator must be readily adaptable for attachment of a dispenser for the reflective media approved for use.

2.1.2.1.2.2 Hand Application

Provide spray guns for hand application of paint in areas where the mobile paint applicator cannot be used.

2.1.2.2 Reflective Media Dispenser

Attach the dispenser for applying the reflective media to the paint dispenser and designed to operate automatically and simultaneously with the applicator through the same control mechanism. The bead applicator must be capable of adjustment and designed to provide uniform flow of reflective media over the full length and width of the stripe at the rate of coverage specified in paragraph APPLICATION.

2.2 MATERIALS

Use waterborne paint for airfield markings. The maximum allowable VOC content of pavement markings is 150 grams per liter. Color of markings are indicated on the drawings and must conform to ASTM D6628 for roads and automotive parking areas and SAE AMS-STD-595A for airfields. Provide materials conforming to the requirements specified herein.

2.2.1 Waterborne Paint

FS TT-P-1952, Type I or II.

2.2.2 Reflective Media

2.2.2.1 Reflective Media for Airfields

FS TT-B-1325, Type I, Gradation A

PART 3 EXECUTION

3.1 EXAMINATION

3.1.1 Testing for Moisture

Test the pavement surface for moisture before beginning pavement marking after each period of rainfall, fog, high humidity, or cleaning, or when the ambient temperature has fallen below the dew point. Do not commence marking until the pavement is sufficiently dry and the pavement condition

has been approved by the Contracting Officer or authorized representative.

Employ the "plastic wrap method" to test the pavement for moisture as follows: Cover the pavement with a 12 inch by 12 inch section of clear plastic wrap and seal the edges with tape. After 15 minutes, examine the plastic wrap for any visible moisture accumulation inside the plastic. Do not begin marking operations until the test can be performed with no visible moisture accumulation inside the plastic wrap. Re-test surfaces when work has been stopped due to rain.

3.1.2 Surface Preparation Demonstration

Prior to surface preparation, demonstrate the proposed procedures and equipment. Prepare areas large enough to determine cleanliness, adhesion of remaining coating and rate of cleaning. Perform a demonstration removal of pavement marking in an area designated by the Contracting Officer. Approved demonstration area establishes the standard for the remainder of the work.

3.1.3 Test Stripe Demonstration

Prior to paint application, demonstrate test stripe application within the work area using the proposed materials and equipment. Apply separate test stripes in each of the line widths and configurations required herein using the proposed equipment. Make the test stripes long enough to determine the proper speed and operating pressures for the vehicle(s) and machinery, but not less than 50 feet long.

3.1.4 Application Rate Demonstration

During the Test Stripe Demonstration, demonstrate compliance with the application rates specified herein. Document the equipment speed and operating pressures required to meet the specified rates in each configuration of the equipment and provide a copy of the documentation to the Contracting Officer prior to proceeding with the work.

3.1.5 Retroreflective Value Demonstration

After the test stripes have cured to a "no-track" condition, demonstrate compliance with the average retroreflective values specified herein. Take a minimum of ten readings on each test stripe with a Retroreflectometer with a direct readout in millicandelas per square meter per lux (mcd/m²/lx). Perform testing in accordance with ASTM D4061, ASTM E1710, ASTM E2177, and ASTM E2302.

3.1.6 Level of Performance Demonstration

The Contracting Officer will be present at the application demonstrations to observe the results obtained and to validate the operating parameters of the vehicle(s) and equipment. If accepted by the Contracting Officer, the test stripe is the measure of performance required for this project. Do not proceed with the work until the demonstration results are satisfactory to the Contracting Officer.

3.2 EXTERIOR SURFACE PREPARATION

Allow new pavement surfaces to cure for a period of not less than 30 days before application of marking materials. Thoroughly clean surfaces to be marked before application of the paint. Remove dust, dirt, and other

granular surface deposits by sweeping, blowing with compressed air, rinsing with water, or a combination of these methods as required. Remove rubber deposits, existing paint markings, residual curing compounds, and other coatings adhering to the pavement by water blasting.

- a. For Portland Cement Concrete pavement, grinding, light shot blasting, or light scarification, to a resulting profile equal to ICRI 03732 CSP 2, CSP 3, and CSP 4, respectively, can be used in addition to water blasting on most pavements, to either remove existing coatings, or for surface preparation.
- b. Do not use shot blasting on airfield pavements due to the potential of Foreign Object Damage (FOD) to aircraft. Scrub affected areas, where oil or grease is present on old pavements to be marked, with several applications of trisodium phosphate solution or other approved detergent or degreaser and rinse thoroughly after each application. After cleaning oil-soaked areas, seal with shellac or primer recommended by the manufacturer to prevent bleeding through the new paint. Do not commence painting in any area until pavement surfaces are dry and clean.

3.2.1 Early Painting of Rigid Pavements

Pretreat rigid pavements that require early painting with an aqueous solution containing 3 percent phosphoric acid and 2 percent zinc chloride. Apply the solution to the areas to be marked.

3.2.2 Early Painting of Asphalt Pavements

For asphalt pavement systems requiring painting application at less than 30 days, apply the paint and beads at half the normal application rate, followed by a second application at the normal rate after 30 days.

3.3 APPLICATION

Apply pavement markings to dry pavements only.

3.3.1 Paint

Apply paint with approved equipment at rate of coverage specified herein. Provide guidelines and templates as necessary to control paint application. Take special precautions in marking numbers, letters, and symbols. Manually paint numbers, letters, and symbols. Sharply outline all edges of markings. The maximum drying time requirements of the paint specifications will be strictly enforced, to prevent undue softening of bitumen, and pickup, displacement, or discoloration by tires of traffic. If there is a deficiency in drying of the markings, painting operations must cease until the cause of the slow drying is determined and corrected.

3.3.1.1 Waterborne Paint

3.3.1.1.1 Airfields

For non-reflectORIZED markings, apply paint conforming to FS TT-P-1952 Type I or II at a rate of 121 plus or minus 6 square feet per gallon.

3.3.2 Cleanup and Waste Disposal

Keep the worksite clean and free of debris and waste from the removal and application operations. Immediately cleanup following removal operations in areas subject to aircraft traffic. Dispose of debris at approved sites.

3.4 FIELD QUALITY CONTROL

3.4.1 Sampling and Testing

As soon as the paint materials and reflective media are available for sampling, obtain by random selection from the sealed containers, two quart samples of each batch in the presence of the Contracting Officer. Accomplish adequate mixing prior to sampling to ensure a uniform, representative sample. A batch is defined as that quantity of material processed by the manufacturer at one time and identified by number on the label. Clearly identify samples by designated name, specification number, batch number, project contract number, intended use, and quantity involved.

At the discretion of the Contracting Officer, samples provided may be tested by the Government for verification.

3.4.2 Material Inspection

Examine material at the job site to determine that it is the material referenced in the report of test results or certificate of compliance. Provide test results substantiating conformance to the specified requirements with each certificate of compliance.

3.4.3 Dimensional Tolerances

Apply all markings in the standard dimensions provide in the drawings. New markings may deviate a maximum of 10 percent larger than the standard dimension. The maximum deviation allowed when painting over an old marking is up to 20 percent larger than the standard dimensions.

3.4.4 Bond Failure Verification

Inspect newly applied markings for signs of bond failure based on visual inspection and comparison to results from Test Stripe Demonstration paragraph.

3.4.5 Reflective Media and Coating Application Verification

Use a wet film thickness gauge to measure the application of wet paint. Use a microscope or magnifying glass to evaluate the embedment of glass beads in the paint. Verify the glass bead embedment with approximately 50 percent of the individual bead spheres embedded and 50 percent of the individual bead spheres exposed.

3.4.6 Material Bond Verification and Operations Area Cleanup for Airfields

Vacuum sweep the aircraft operating area before it is opened for aircraft operations to preclude potential foreign object damaged to aircraft engines. Visually inspect the pavement markings and the material captured by the vacuum. Verify that no significant loss of reflective media has occurred to the pavement marking due to the vacuum cleaning.

-- End of Section --

SECTION 32 92 19

SEEDING
08/17

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM C602	(2019) Agricultural Liming Materials
ASTM D4427	(2018) Standard Classification of Peat Samples by Laboratory Testing
ASTM D4972	(2018) Standard Test Methods for pH of Soils

U.S. DEPARTMENT OF AGRICULTURE (USDA)

AMS Seed Act	(1940; R 1988; R 1998) Federal Seed Act
DOA SSIR 42	(1996) Soil Survey Investigation Report No. 42, Soil Survey Laboratory Methods Manual, Version 3.0

1.2 DEFINITIONS

1.2.1 Stand of Turf

95 percent ground cover of the established species.

1.3 RELATED REQUIREMENTS

Section 31 00 00 EARTHWORK applies to this section for pesticide use and plant establishment requirements, with additions and modifications herein.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance with Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Wood Cellulose Fiber Mulch

Fertilizer

Include physical characteristics, and recommendations.

SD-06 Test Reports

Topsoil Composition Tests (reports and recommendations).

SD-07 Certificates

State Certification and Approval for Seed

1.5 DELIVERY, STORAGE, AND HANDLING

1.5.1 Delivery

1.5.1.1 Seed Protection

Protect from drying out and from contamination during delivery, on-site storage, and handling.

1.5.1.2 Fertilizer, Sulfur, and Lime Delivery

Deliver to the site in original, unopened containers bearing manufacturer's chemical analysis, name, trade name, trademark, and indication of conformance to state and federal laws. Instead of containers, fertilizer, sulfur, and lime may be furnished in bulk with certificate indicating the above information.

1.5.2 Storage

1.5.2.1 Seed, Fertilizer, Sulfur, and Lime Storage

Store in cool, dry locations away from contaminants.

1.5.2.2 Topsoil

Prior to stockpiling topsoil, treat growing vegetation with application of appropriate specified non-selective herbicide. Clear and grub existing vegetation three to four weeks prior to stockpiling topsoil.

1.5.2.3 Handling

Do not drop or dump materials from vehicles.

1.6 TIME RESTRICTIONS AND PLANTING CONDITIONS

1.6.1 Restrictions

Do not plant when the ground is frozen, snow covered, muddy, or when air temperature exceeds 90 degrees Fahrenheit.

1.7 TIME LIMITATIONS

1.7.1 Seed

Apply seed within twenty-four hours after seed bed preparation.

PART 2 PRODUCTS

2.1 SEED

2.1.1 Classification

Provide State-certified, Full Sun, Warm Season Bermudagrass (Cynodon dactylon) seed of the latest season's crop delivered in original sealed packages, bearing producer's guaranteed analysis for percentages of mixtures, purity, germination, weed seed content, and inert material. Label in conformance with AMS Seed Act and applicable state seed laws. Wet, moldy, or otherwise damaged seed will be rejected.

2.1.2 Planting Dates

<u>Planting Season</u>	<u>Planting Dates</u>
Spring	February 1 through May 1
Fall	September 1 through October 15
Temporary Seeding	June 1 - August 1

2.1.3 Seed Purity

Botanical Name	Common Name	Minimum Percent Pure Seed	Minimum Percent Germination and Hard Seed	Maximum Percent Weed Seed
Cynodon dactylon	Bermudagrass	97	85	1.00

2.2 TOPSOIL

2.2.1 On-Site Topsoil

Surface soil stripped and stockpiled on site and modified as necessary to meet the requirements specified for topsoil in paragraph COMPOSITION. When available topsoil must be existing surface soil stripped and stockpiled on-site in accordance with Section 31 00 00 EARTHWORK.

2.2.2 Off-Site Topsoil

Conform to requirements specified in paragraph COMPOSITION. Additional topsoil must be furnished by the Contractor.

2.2.3 Composition

Containing from 5 to 10 percent organic matter as determined by the topsoil composition tests of the Organic Carbon, 6A, Chemical Analysis Method described in DOA SSIR 42. Maximum particle size, 3/4 inch, with maximum 3 percent retained on 1/4-inch screen. The pH must be tested in

accordance with ASTM D4972 and fall between 5.5 and 7.0. Topsoil must be free of sticks, stones, roots, and other debris and objectionable materials.

2.3 SOIL CONDITIONERS

Add conditioners to topsoil as required to bring into compliance with "composition" standard for topsoil as specified herein.

2.3.1 Lime

Commercial grade hydrate limestone containing a calcium carbonate equivalent (C.C.E.) as specified in ASTM C602 of not less than 110 percent.

2.3.2 Aluminum Sulfate

Commercial grade.

2.3.3 Sulfur

100 percent elemental

2.3.4 Iron

100 percent elemental

2.3.5 Peat

Natural product of peat moss derived from a freshwater site and conforming to ASTM D4427. Shred and granulate peat to pass a 1/2 inch mesh screen and condition in storage pile for minimum 6 months after excavation.

2.3.6 Sand

Clean and free of materials harmful to plants.

2.3.7 Perlite

Horticultural grade.

2.3.8 Composted Derivatives

Ground bark, nitrolized sawdust, humus or other green wood waste material free of stones, sticks, and soil stabilized with nitrogen and having the following properties:

2.3.8.1 Particle Size

Minimum percent by weight passing:

No. 4 mesh screen	95
No. 8 mesh screen	80

2.3.8.2 Nitrogen Content

Minimum percent based on dry weight:

Fir Sawdust	0.7
Fir or Pine Bark	1.0

2.3.9 Gypsum

Coarsely ground gypsum comprised of calcium sulfate dihydrate 80 percent, calcium 18 percent, sulfur 14 percent; minimum 96 percent passing through 20 mesh screen, 100 percent passing thru 16 mesh screen.

2.3.10 Calcined Clay

Calcined clay must be granular particles produced from montmorillonite clay calcined to a minimum temperature of 1200 degrees F. Gradation: A minimum 90 percent must pass a No. 8 sieve; a minimum 99 percent must be retained on a No. 60 sieve; and material passing a No. 100 sieve must not exceed 2 percent. Bulk density: A maximum 40 pounds per cubic foot.

2.4 FERTILIZER

Fertilizer shall be of the type and composition recommended by the seed supplier, but at a minimum shall be 0.5 pounds of Nitrogen per 1,000 sq ft as recommended by the local Agriculture County Extension Service Office.

2.5 MULCH

Mulch must be free from noxious weeds, mold, and other deleterious materials.

2.5.1 Wood Cellulose Fiber Mulch

Use recovered materials of either paper-based (100 percent post-consumer content) or wood-based (100 percent total recovered content) hydraulic mulch. Processed to contain no growth or germination-inhibiting factors and dyed an appropriate color to facilitate visual metering of materials application. Composition on air-dry weight basis: 9 to 15 percent moisture, pH range from 5.5 to 8.2. Use with hydraulic application of grass seed and fertilizer.

2.6 WATER

Source of water must be approved by Contracting Officer and of suitable quality for irrigation, containing no elements toxic to plant life.

PART 3 EXECUTION

3.1 PREPARATION

3.1.1 EXTENT OF WORK

Provide soil preparation prior to planting (including soil conditioners as required), fertilizing, seeding, and surface topdressing of all newly graded finished earth surfaces, unless indicated otherwise, and at all areas inside or outside the limits of construction that are disturbed by the Contractor's operations.

3.1.1.1 Topsoil

Provide 4 inches of topsoil to meet indicated finish grade. After areas have been brought to indicated finish grade, incorporate fertilizer and pH adjusters, as necessary, into soil a minimum depth of 4 inches by disking, harrowing, tilling or other method approved by the Contracting Officer.

Remove debris and stones larger than 3/4 inch in any dimension remaining on the surface after finish grading. Correct irregularities in finish surfaces to eliminate depressions. Protect finished topsoil areas from damage by vehicular or pedestrian traffic.

3.1.1.2 Fertilizer Application Rates

Apply fertilizer at rates as determined by laboratory soil analysis of the soils at the job site. For bidding purposes only apply at 0.5 pounds per 1,000 sq ft.

3.2 SEEDING

3.2.1 Seed Application Seasons and Conditions

Immediately before seeding, restore soil to proper grade. Do not seed when ground is muddy, frozen, snow covered, or in an unsatisfactory condition for seeding. If special conditions exist that may warrant a variance in the above seeding dates or conditions, submit a written request to the Contracting Officer stating the special conditions and proposed variance. Apply seed within twenty-four hours after seedbed preparation. Sow seed by approved sowing equipment.

3.2.2 Seed Application Method

Seeding method must be hydroseeding.

3.2.2.1 Hydroseeding

First, mix water and fiber. Wood cellulose fiber, paper fiber, or recycled paper must be applied as part of the hydroseeding operation. Fiber must be added at 1,000 pounds, dry weight, per acre. Then add and mix seed and fertilizer to produce a homogeneous slurry. Seed must be mixed to ensure broadcasting at the rate of 3 pounds per 1000 square feet. When hydraulically sprayed on the ground, material must form a blotter like cover impregnated uniformly with grass seed. Spread with one application with no second application of mulch.

3.2.3 Mulching

3.2.3.1 Non-Asphaltic Tackifier

Hydrophilic colloid must be applied at the rate recommended by the manufacturer, using hydraulic equipment suitable for thoroughly mixing with water. A uniform mixture must be applied over the area.

3.2.4 Erosion Control Material

Install in accordance with manufacturer's instructions, where indicated or as directed by the Contracting Officer.

3.2.5 Watering

Start watering areas seeded as required by temperature and wind conditions. Apply water at a rate sufficient to ensure thorough wetting of soil to a depth of 2 inches without run off. During the germination process, seed is to be kept actively growing and not allowed to dry out.

3.3 PROTECTION OF TURF AREAS

Immediately after turfing, protect area against traffic and other use.

3.4 RESTORATION

Restore to original condition existing turf areas which have been damaged during turf installation operations at the Contractor's expense. Keep clean at all times at least one paved pedestrian access route and one paved vehicular access route to each building. Clean other paving when work in adjacent areas is complete.

-- End of Section --

SECTION 33 40 00

STORMWATER UTILITIES

11/21

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
(AASHTO)

AASHTO HB-17 (2002; Errata 2003; Errata 2005, 17th Edition) Standard Specifications for Highway Bridges

ASTM INTERNATIONAL (ASTM)

ASTM A48/A48M (2003; R 2021) Standard Specification for Gray Iron Castings

ASTM A123/A123M (2017) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

ASTM A536 (1984; R 2019; E 2019) Standard Specification for Ductile Iron Castings

ASTM B26/B26M (2018; E 2018) Standard Specification for Aluminum-Alloy Sand Castings

ASTM C32 (2023) Standard Specification for Sewer and Manhole Brick (Made from Clay or Shale)

ASTM C55 (2022) Standard Specification for Concrete Building Brick

ASTM C62 (2023) Standard Specification for Building Brick (Solid Masonry Units Made from Clay or Shale)

ASTM C76 (2022a) Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe

ASTM C76M (2022a) Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe (Metric)

ASTM C139 (2022) Standard Specification for Concrete Masonry Units for Construction of Catch Basins and Manholes

ASTM C231/C231M (2024) Standard Test Method for Air Content of Freshly Mixed Concrete by the

Pressure Method

ASTM C270	(2019a; E 2019) Standard Specification for Mortar for Unit Masonry
ASTM C443	(2021) Standard Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets
ASTM C478/C478M	(2022) Standard Specification for Circular Precast Reinforced Concrete Manhole Sections
ASTM D1751	(2018) Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
ASTM D1752	(2018) Standard Specification for Preformed Sponge Rubber, Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction
ASTM D2321	(2020) Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications

1.2 SUBMITTALS

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-06 Test Reports

SD-08 Manufacturer's Instructions

Placing Pipe and Box Culvert; G

SD-11 Closeout Submittals

Post-Installation Inspection Report; G

1.3 DELIVERY, STORAGE, AND HANDLING

1.3.1 Delivery and Storage

Inspect materials delivered to site for damage and unload and store materials with minimal handling. Do not store materials directly on the ground. Keep the inside of pipes and fittings free of dirt and debris. Before, during, and after installation, protect plastic pipe and fittings from any environment that would result in damage or deterioration to the material. Keep a copy of the manufacturer's instructions available at the construction site at all times and follow these instructions unless directed otherwise by the Contracting Officer. Store solvents, solvent compounds, lubricants, elastomeric gaskets, and any similar materials required to install plastic pipe in accordance with the manufacturer's

recommendations and discard if the storage period exceeds the recommended shelf life. Discard solvents in use when the recommended pot life is exceeded.

1.3.2 Handling

Handle materials in a manner that ensures delivery to the trench in sound, undamaged condition. Carry pipe to the trench.

PART 2 PRODUCTS

2.1 PIPE FOR CULVERTS AND STORM DRAINS

Pipe sizes for culverts and storm drains are indicated on the drawings.

2.1.1 Concrete Pipe

2.1.1.1 Reinforced Culvert and Storm Drain Pipe

Manufactured in accordance with and conforming to ASTM C76M ASTM C76, Class IV.

2.2 PIPE JOINTS

2.2.1 Concrete Pipe

2.2.1.1 Rubber Gasket Joints

Provide rubber gasket joints of a design and physical requirements conforming to ASTM C443.

2.3 MISCELLANEOUS MATERIALS

2.3.1 Concrete

Unless otherwise specified, provide concrete and reinforced concrete conforming to the requirements for 3500 psi concrete under Section 03 30 00 CAST-IN-PLACE CONCRETE. Provide air content by volume of concrete mixture, based on measurements made immediately after discharge from the mixer, of 5 to 7 percent when maximum size of coarse aggregate exceeds 1-1/2 inches. Determine air content in accordance with ASTM C231/C231M. Provide a minimum concrete covering over steel reinforcing of not less than 1 inch thick for covers and not less than 1-1/2 inches thick for walls and flooring. For concrete deposited directly against the ground, provide a covering thickness of at least 3 inches between steel and ground. Provide expansion-joint filler material conforming to ASTM D1751, or ASTM D1752, or provide be resin-impregnated fiberboard conforming to the physical requirements of ASTM D1752.

2.3.2 Mortar

Mortar is not allowed for pipe joints. Provide mortar for pipe connections to drainage structures conforming to ASTM C270, Type M, except that the maximum placement time will be 1 hour. Provide a sufficient quantity of water in the mixture to produce a stiff workable mortar but in no case may the quantity exceed 5 gallons of water per sack of cement. Use water that is clean and free of harmful acids, alkalis, and organic impurities. Use the mortar within 30 minutes after the ingredients are mixed with water.

2.3.3 Precast Concrete Segmental Blocks

Provide precast concrete segmental block conforming to ASTM C139, not more than 8 inches thick, not less than 8 inches long, and of such shape that joints can be sealed effectively and bonded with cement mortar.

2.3.4 Brick

Provide brick conforming to ASTM C62, Grade SW; ASTM C55, Grade S-I or S-II; or ASTM C32, Grade MS. Provide mortar for jointing and plastering consisting of one part Portland cement and two parts fine sand. Lime may be added to the mortar in a quantity not more than 25 percent of the volume of cement. Provide joints that are completely filled and that are smooth and free from surplus mortar on the inside of the structure. Plaster brick structures with 1/2 inch of mortar over the entire outside surface of the walls. Lay brick in stretcher courses with a header course every sixth course for square or rectangular structures. Lay brick radially with every sixth course a stretcher course for round structures.

2.3.5 Precast Reinforced Concrete Manholes

Provide precast reinforced concrete manholes conforming to ASTM C478/C478M. Provide joints between precast concrete risers and tops that are full-bedded in cement mortar and smoothed to a uniform surface on both interior and exterior of the structure or made with flexible watertight, rubber-type gaskets meeting the requirements of paragraph PIPE JOINTS.

2.3.6 Frame and Cover or Gratings

Provide frame and cover or gratings made of cast gray iron, ASTM A48/A48M, Class 35B; cast ductile iron, ASTM A536, Grade 65-45-12; or cast aluminum, ASTM B26/B26M, Alloy 356.0-T6. Provide curb inlet grates conforming to the weight, shape, size, and waterway openings indicated on the plans. Stamp or cast the word "Storm Sewer" into covers so that it is plainly visible.

2.3.7 Steel Ladder

Provide a steel ladder where the depth of the storm drainage structure exceeds 12 feet. Provide ladders not less than 16 inches in width, with 3/4 inch diameter rungs spaced 12 inches apart. Provide two stringers that are a minimum 3/8 inch thick and 2-1/2 inches wide. Galvanize ladders and inserts after fabrication in conformance with ASTM A123/A123M.

2.3.8 Trench Drains

2.3.8.1 Grates

Utilize ductile iron trench grates. Attach trench grates to sections as recommended by the manufacturer.

PART 3 EXECUTION

3.1 EXCAVATION FOR PIPE CULVERTS, BOX CULVERTS, STORM DRAINS, AND DRAINAGE STRUCTURES

Excavate trenches, excavate for appurtenances and backfill for culverts and storm drains, in accordance with the applicable portions of Section

31 00 00 EARTHWORK and the requirements specified below.

3.1.1 Trenching

Excavate trenches to the width indicated on the drawings or as specified herein. Trench width should permit satisfactory jointing and thorough tamping of the bedding material under and around the pipe. Place sheeting and bracing, where required, within the trench width as specified, without any over-excavation.

3.1.2 Removal of Rock

Replace rock in either ledge or boulder formation with suitable materials to provide a compacted earth cushion. Provide a compacted earth cushion between unremoved rock and the pipe with a thickness of at least 8 inches or 1/2 inch for each foot of fill over the top of the pipe, whichever is greater, but not more than three-fourths the nominal diameter of the pipe. Maintain the cushion under the bell as well as under the straight portion of the pipe where bell-and-spigot pipe is used. Provide a compacted earth cushion between unremoved rock and the box culvert of at least 8 inches in thickness for concrete box culverts. Excavate rock as specified and defined in Section 31 00 00 EARTHWORK.

3.1.3 Removal of Unstable Material

Where wet or otherwise unstable soil incapable of properly supporting the pipe or box culvert, as determined by the Contracting Officer, is unexpectedly encountered in the bottom of a trench, remove such material to the depth required and replace with select granular material to the proper grade. Compact select granular material as specified in paragraph FINAL BACKFILL. When removal of unstable material is due to the fault or neglect of the Contractor while performing shoring and sheeting, water removal, or other specified requirements, perform such removal and replacement at no additional cost to the Government.

3.2 BEDDING AND INITIAL BACKFILL

Provide a firm bedding foundation of uniform density throughout the entire length of the pipe or box culvert.

3.2.1 Concrete Pipe

Use select granular material conforming to Section 31 00 00 EARTHWORK for haunch and bedding material. Compact haunch and outer bedding to at least 90 percent laboratory maximum density and place in layers not exceeding 6 inch loose thickness for compaction by hand-operated compactors and 200 mm 8 inches for other than hand-operated machines. Loosely place middle bedding and do not compact. After the pipe has been properly bedded, place haunch material, at a moisture content that will facilitate compaction, evenly along both sides of the pipe and thoroughly compact each layer with mechanical tampers or rammers to the springline of the pipe. Thoroughly compact the haunch material under the haunches of the pipe. For bell and spigot pipe, form a depression in bedding material for bells so entire barrel of pipe is uniformly supported. Minimize the length, depth, and width of bell depressions to that required for properly making the particular type of joint.

3.2.1.1 Trenches

After the pipe has been properly bedded and haunch material placed to the midpoint (springline) of the pipe, backfill and compact the remainder of the trench by spreading and rolling or compacting by mechanical rammers or tampers in layers not exceeding 6 inches. Test for density as necessary to ensure conformance to the compaction requirements specified below. Where it is necessary, in the opinion of the Contracting Officer, that sheeting or portions of bracing used be left in place, the contract will be adjusted accordingly. Leave untreated sheeting in place beneath structures or pavements.

3.2.1.2 Fill Sections

For pipe placed in fill sections, uniformly spread fill material longitudinally on both sides of the pipe in layers not exceeding 6 inches in compacted depth, and compact by rolling parallel with pipe or by mechanical tamping or ramming. Prior to commencing normal filling operations, the crown width of the fill at a height of 12 inches above the top of the pipe must extend a distance of not less than twice the outside pipe diameter on each side of the pipe or 12 feet, whichever is less. After the backfill has reached at least 12 inches above the top of the pipe, place and thoroughly compact the remainder of the fill in layers not exceeding 8 inches.

3.3 PLACING PIPE AND BOX CULVERT

Submit printed copies of the pipe or box culvert manufacturer's recommended pipe or box culvert installation procedures prior to installation. Thoroughly examine each section of pipe or box culvert before being laid; do not use defective or damaged pipe. Protect plastic pipe, excluding SRPE pipe, from exposure to direct sunlight prior to laying, if necessary to maintain adequate pipe stiffness and meet installation deflection requirements. Lay pipelines to the grades and alignment indicated. Provide proper facilities for lowering sections of pipe into trenches. Do not lay pipe in water or when trench conditions or weather are unsuitable for such work. Divert drainage or dewater trenches during construction as necessary.

3.3.1 Concrete, Clay, PVC, Ribbed PVC, Ductile Iron Pipe

Lay pipe proceeding upgrade with spigot ends of bell-and-spigot pipe and tongue ends of tongue-and-groove pipe pointing in the direction of the flow.

3.4 JOINTING

3.4.1 Concrete and Clay Pipe

3.4.1.1 Plastic Sealing Compound Joints for Tongue-and-Grooved Pipe and Box Culverts

Follow the recommendation of the particular manufacturer in regard to sealing compound special installation requirements. When lubricants, primers, or adhesives are used, only apply on surfaces that are dry and clean. Affix sealing compounds to the pipe or box culvert not more than 3 hours prior to installation of the pipe or box culvert. Protect sealing compounds from the sun, blowing dust, and other deleterious agents at all times. Inspect sealing compounds before installation of the pipe or box

culvert, and remove and replace any loose or improperly affixed sealing compound. Align the pipe or box culvert with the previously installed pipe or box culvert, and pull the joint together.

3.4.1.2 Flexible Watertight Joints

Use lubricants, cements, adhesives, and other special installation requirements for gaskets and jointing materials as recommended by the manufacturer. When lubricants, cements, or adhesives are used, only apply on surfaces that are clean and dry. Affix gaskets and jointing materials to the pipe not more than 24 hours prior to the installation of the pipe, and protect from the sun, blowing dust, and other deleterious agents at all times. Inspect gaskets and jointing materials before installing the pipe; remove and replace any loose or improperly affixed gaskets and jointing materials. Align the pipe with the previously installed pipe, and push the joint home. If the gasket becomes visibly dislocated when joining sections of pipe, remove the pipe and remake the joint.

3.5 DRAINAGE STRUCTURES

3.5.1 Manholes and Inlets

Construct manholes of precast reinforced concrete. Construct inlets of precast reinforced concrete. Provide manholes and inlets complete with frames and covers or gratings; and with fixed galvanized steel ladders as indicated. The wall along the line where steel ladders are installed must be vertical for its entire length. Adequately anchor ladders to the wall by means of steel inserts spaced not more than 6 feet vertically, and install to provide at least 6 inches of space between the wall and the rungs.

3.6 INSTALLATION OF TRACER WIRE AND WARNING TAPE

Install warning tape above all storm drain pipe in accordance with Section 31 00 00 EARTHWORK.

3.7 FINAL BACKFILL

Backfill trenches with satisfactory material deposited in layers of a maximum of 8 inches loose thickness and compacted to 90 percent of maximum density for cohesive soils and 95 percent of maximum density for cohesionless soils in accordance with Section 31 00 00 EARTHWORK. Testing is the responsibility of the Contractor and will be performed at no additional cost to the Government. Unless otherwise specified, determine field in-place density of final backfill at a frequency of one test per 50 linear feet, or fraction thereof, of each lift of backfill. Submit test results in accordance with Section 31 00 00 EARTHWORK. Do not displace or damage pipe or box when compacting final backfill by rolling or operating heavy equipment parallel with the pipe or box. Movement of construction machinery over a culvert or storm drain at any stage of construction will be at the Contractor's risk. Repair or replace any damaged pipe. Protect concrete pipes with a minimum of 3 feet of cover prior to permitting heavy construction equipment to pass over them during construction. Provide the minimum cover for construction loads over corrugated steel pipes as specified in Section 26, Division II of AASHTO HB-17. Provide minimum cover for construction loads over plastic pipes as specified in ASTM D2321.

3.8 FIELD QUALITY CONTROL

3.8.1 Tests

Testing is the responsibility of the Contractor. Perform all testing and retesting at no additional cost to the Government.

3.8.2 Inspection

3.8.2.1 Post-Installation Inspection

Inspect each segment of pipe for alignment, settlement, joint separations, soil migration through the joint, cracks, buckling, bulging and deflection. An engineer must evaluate all defects to determine if any remediation or repair is required.

3.8.2.1.1 Concrete Pipe

An engineer must evaluate all pipes with cracks with a width greater than 0.25 mm 0.01 inches, but less than 0.10 inches to determine if any remediation or repair is required.

3.8.2.1.2 Post-Installation Inspection Report

The final post installation inspection report must include: pipe location identification, equipment used for inspection, inspector name, deviation from design, grade, deviation from line, deflection and deformation of flexible pipe, inspector notes, condition of joints, condition of pipe wall (e.g. distress, cracking, wall damage dents, bulges, creases, tears, holes, etc.).

3.8.3 Repair of Defects

3.8.3.1 Inspection

Replace pipe or repair defects indicated in the Post-Installation Inspection Report.

3.8.3.1.1 Concrete Pipe

Replace pipes having cracks with a width greater than 0.1 inches.

3.9 PROTECTION

Protect storm drainage piping and adjacent areas from superimposed and external loads during construction.

3.10 WARRANTY PERIOD

Pipe segments found to have defects during the warranty period must be replaced with new pipe and retested.

-- End of Section --

SECTION 33 82 00

TELECOMMUNICATIONS OUTSIDE PLANT (OSP)

04/06

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

- | | |
|-----------|---|
| ASTM B1 | (2013) Standard Specification for Hard-Drawn Copper Wire |
| ASTM B8 | (2023) Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft |
| ASTM D709 | (2017) Standard Specification for Laminated Thermosetting Materials |

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

- | | |
|----------|---|
| IEEE 100 | (2000; Archived) The Authoritative Dictionary of IEEE Standards Terms |
| IEEE C2 | (2023) National Electrical Safety Code |

INSULATED CABLE ENGINEERS ASSOCIATION (ICEA)

- | | |
|---------------|--|
| ICEA S-87-640 | (2016) Optical Fiber Outside Plant Communications Cable; 4th Edition |
| ICEA S-98-688 | (2012) Broadband Twisted Pair Telecommunication Cable, Aircore, Polyolefin Insulated, Copper Conductors Technical Requirements |
| ICEA S-99-689 | (2012) Broadband Twisted Pair Telecommunication Cable Filled, Polyolefin Insulated, Copper Conductors Technical Requirements |

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

- | | |
|-------------|--|
| ANSI C62.61 | (1993) American National Standard for Gas Tube Surge Arresters on Wire Line Telephone Circuits |
|-------------|--|

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- | | |
|---------|---|
| NFPA 70 | (2023; ERTA 7 2023; TIA 23-15) National Electrical Code |
|---------|---|

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-455-107	(1999a) FOTP-107 Determination of Component Reflectance or Link/System Return Loss using a Loss Test Set
TIA-455-78-B	(2002) FOTP-78 Optical Fibres - Part 1-40: Measurement Methods and Test Procedures - Attenuation
TIA-472D000	(2007b) Fiber Optic Communications Cable for Outside Plant Use
TIA-492CAAA	(1998; R 2002) Detail Specification for Class IVa Dispersion-Unshifted Single-Mode Optical Fibers
TIA-526-14	(2015c) OFSTP-14A Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant
TIA-526-7	(2015a) OFSTP-7 Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant
TIA-568-C.1	(2009; Add 2 2011; Add 1 2012) Commercial Building Telecommunications Cabling Standard
TIA-568-C.2	(2009; Errata 2010; Add 2 2014; Add 1 2016) Balanced Twisted-Pair Telecommunications Cabling and Components Standards
TIA-568-C.3	(2008; Add 1 2011) Optical Fiber Cabling Components Standard
TIA-569	(2019e; Add 1 2022) Telecommunications Pathways and Spaces
TIA-590	(1997a) Standard for Physical Location and Protection of Below Ground Fiber Optic Cable Plant
TIA-606	(2021d) Administration Standard for Telecommunications Infrastructure
TIA-607	(2019d) Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises
TIA-758	(2012b) Customer-Owned Outside Plant Telecommunications Infrastructure Standard
TIA/EIA-455	(1998b) Standard Test Procedure for Fiber Optic Fibers, Cables, Transducers, Sensors, Connecting and Terminating Devices, and Other Fiber Optic Components

TIA/EIA-455-204 (2000) Standard for Measurement of Bandwidth on Multimode Fiber

TIA/EIA-598 (2014D; Add 2 2018) Optical Fiber Cable Color Coding

U.S. DEPARTMENT OF AGRICULTURE (USDA)

RUS 1755 Telecommunications Standards and Specifications for Materials, Equipment and Construction

RUS Bull 1751F-630 (1996) Design of Aerial Plant

RUS Bull 1751F-643 (2002) Underground Plant Design

RUS Bull 1751F-815 (1979) Electrical Protection of Outside Plant

RUS Bull 1753F-201 (1997) Acceptance Tests of Telecommunications Plant (PC-4)

RUS Bull 1753F-401 (1995) Splicing Copper and Fiber Optic Cables (PC-2)

RUS Bull 345-72 (1985) Filled Splice Closures (PE-74)

RUS Bull 345-83 (1979; Rev Oct 1982) Gas Tube Surge Arrestors (PE-80)

UNDERWRITERS LABORATORIES (UL)

UL 497 (2001; Reprint Jul 2013) Protectors for Paired Conductor Communication Circuits

UL 510 (2020; Dec 2022) UL Standard for Safety Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape

UL 83 (2017; Reprint Mar 2020) UL Standard for Safety Thermoplastic-Insulated Wires and Cables

1.2 RELATED REQUIREMENTS

Section 27 10 00, BUILDING TELECOMMUNICATIONS CABLING SYSTEM, and Section 33 71 02, UNDERGROUND ELECTRICAL DISTRIBUTION apply to this section with additions and modifications specified herein.

1.3 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in this specification shall be as defined in TIA-568-C.1, TIA-568-C.2, TIA-568-C.3, TIA-569, TIA-606, and IEEE 100 and herein.

1.3.1 Campus Distributor (CD)

A distributor from which the campus backbone cabling emanates.
(International expression for main cross-connect - (MC).)

1.3.2 Entrance Facility (EF) (Telecommunications)

An entrance to the building for both private and public network service cables (including antennae) including the entrance point at the building wall and continuing to the entrance room or space.

1.3.3 Entrance Room (ER) (Telecommunications)

A centralized space for telecommunications equipment that serves the occupants of a building. Equipment housed therein is considered distinct from a telecommunications room because of the nature of its complexity.

1.3.4 Building Distributor (BD)

A distributor in which the building backbone cables terminate and at which connections to the campus backbone cables may be made. (International expression for intermediate cross-connect - (IC).)

1.3.5 Pathway

A physical infrastructure utilized for the placement and routing of telecommunications cable.

1.4 SYSTEM DESCRIPTION

The telecommunications outside plant consists of cable, conduit, manholes, poles, etc. required to provide signal paths from the closest point of presence to the new facility, including free standing frames or backboards, interconnecting hardware, terminating cables, lightning and surge protection modules at the entrance facility. The work consists of providing, testing and making operational cabling, interconnecting hardware and lightning and surge protection necessary to form a complete outside plant telecommunications system for continuous use.

1.5 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Telecommunications Outside Plant; G

Telecommunications Entrance Facility Drawings; G

In addition to Section 01 33 00 SUBMITTAL PROCEDURES, provide shop drawings in accordance with paragraph SHOP DRAWINGS.

SD-03 Product Data

Wire and cable; G

Cable splices, and connectors; G

Closures; G

Building protector assemblies; G

Protector modules; G

SD-06 Test Reports

Pre-installation tests; G

Acceptance tests; G

Outside Plant Test Plan; G

SD-07 Certificates

Telecommunications Contractor Qualifications; G

Key Personnel Qualifications; G

Minimum Manufacturer's Qualifications; G

SD-08 Manufacturer's Instructions

Building protector assembly installation; G

Cable tensions; G

Fiber Optic Splices; G

Submit instructions prior to installation.

SD-09 Manufacturer's Field Reports

Factory Reel Test Data; G

SD-11 Closeout Submittals

Record Documentation; G

In addition to other requirements, provide in accordance with paragraph RECORD DOCUMENTATION.

1.6 QUALITY ASSURANCE

1.6.1 Shop Drawings

Include wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Wiring diagrams shall identify circuit terminals and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Drawings shall indicate adequate clearance for operation, maintenance, and replacement of operating equipment devices. Submittals shall include the nameplate data, size, and capacity. Submittals shall also include applicable federal, military, industry, and technical society publication references.

1.6.1.1 Telecommunications Outside Plant Shop Drawings

Provide Outside Plant Design in accordance with TIA-758, RUS Bull 1751F-630 for aerial system design, and RUS Bull 1751F-643 for underground system design. Provide T0 shop drawings that show the physical and logical connections from the perspective of an entire campus, such as actual building locations, exterior pathways and campus backbone cabling on plan view drawings, major system nodes, and related connections on the logical system drawings in accordance with TIA-606. Drawings shall include wiring and schematic diagrams for fiber optic and copper cabling and splices, copper conductor gauge and pair count, fiber pair count and type, pathway duct and innerduct arrangement, associated construction materials, and any details required to demonstrate that cable system has been coordinated and will properly support the switching and transmission system identified in specification and drawings. Provide Registered Communications Distribution Designer (RCDD) approved drawings of the telecommunications outside plant.

1.6.1.2 Telecommunications Entrance Facility Drawings

Provide T3 drawings for EF Telecommunications in accordance with TIA-606 that include telecommunications entrance facility plan views, pathway layout (cable tray, racks, ladder-racks, etc.), mechanical/electrical layout, and, backboard and wall elevations. Drawings shall show layout of applicable equipment including incoming cable stub or connector blocks, building protector assembly, outgoing cable connector blocks, patch panels and equipment spaces and cabinet/racks. Drawings shall include a complete list of equipment and material, equipment rack details, proposed layout and anchorage of equipment and appurtenances, and equipment relationship to other parts of the work including clearance for maintenance and operation. Drawings may also be an enlargement of a congested area of T1 or T2 drawings. Provide T3 drawings for EF Telecommunications as specified in the paragraph TELECOMMUNICATIONS SPACE DRAWINGS of Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEMS.

1.6.2 Telecommunications Qualifications

Work under this section shall be performed by and the equipment shall be provided by the approved telecommunications contractor and key personnel. Qualifications shall be provided for: the telecommunications system contractor, the telecommunications system installer, the supervisor (if different from the installer), and the cable splicing and terminating personnel. A minimum of 30 days prior to installation, submit documentation of the experience of the telecommunications contractor and of the key personnel.

1.6.2.1 Telecommunications Contractor Qualifications

The telecommunications contractor shall be a firm which is regularly and professionally engaged in the business of the applications, installation, and testing of the specified telecommunications systems and equipment. The telecommunications contractor shall demonstrate experience in providing successful telecommunications systems that include outside plant and broadband cabling within the past 3 years. Submit documentation for a minimum of three and a maximum of five successful telecommunication system installations for the telecommunications contractor. Each of the key personnel shall demonstrate experience in providing successful telecommunications systems in accordance with TIA-758 within the past 3 years.

1.6.2.2 Key Personnel Qualifications

Provide key personnel who are regularly and professionally engaged in the business of the application, installation and testing of the specified telecommunications systems and equipment. There may be one key person or more key persons proposed for this solicitation depending upon how many of the key roles each has successfully provided. Each of the key personnel shall demonstrate experience in providing successful telecommunications systems within the past 3 years.

Cable splicing and terminating personnel assigned to the installation of this system or any of its components shall have training in the proper techniques and have a minimum of 3 years experience in splicing and terminating the specified cables. Modular splices shall be performed by factory certified personnel or under direct supervision of factory trained personnel for products used.

Supervisors and installers assigned to the installation of this system or any of its components shall have factory or factory approved certification from each equipment manufacturer indicating that they are qualified to install and test the provided products.

Submit documentation for a minimum of three and a maximum of five successful telecommunication system installations for each of the key personnel. Documentation for each key person shall include at least two successful system installations provided that are equivalent in system size and in construction complexity to the telecommunications system proposed for this solicitation. Include specific experience in installing and testing telecommunications outside plant systems, including broadband cabling, and provide the names and locations of at least two project installations successfully completed using optical fiber and copper telecommunications cabling systems. All of the existing telecommunications system installations offered by the key persons as successful experience shall have been in successful full-time service for at least 18 months prior to the issuance date for this solicitation. Provide the name and role of the key person, the title, location, and completed installation date of the referenced project, the referenced project owner point of contact information including name, organization, title, and telephone number, and generally, the referenced project description including system size and construction complexity.

Indicate that all key persons are currently employed by the telecommunications contractor, or have a commitment to the telecommunications contractor to work on this project. All key persons shall be employed by the telecommunications contractor at the date of issuance of this solicitation, or if not, have a commitment to the telecommunications contractor to work on this project by the date that the bid was due to the Contracting Officer.

Note that only the key personnel approved by the Contracting Officer in the successful proposal shall do work on this solicitation's telecommunications system. Key personnel shall function in the same roles in this contract, as they functioned in the offered successful experience. Any substitutions for the telecommunications contractor's key personnel requires approval from The Contracting Officer.

1.6.2.3 Minimum Manufacturer's Qualifications

Cabling, equipment and hardware manufacturers shall have a minimum of 3 years experience in the manufacturing, assembly, and factory testing of components which comply with, TIA-568-C.1, TIA-568-C.2 and TIA-568-C.3. In addition, cabling manufacturers shall have a minimum of 3 years experience in the manufacturing and factory testing of cabling which comply with ICEA S-87-640, ICEA S-98-688, and ICEA S-99-689.

1.6.3 Outside Plant Test Plan

Prepare and provide a complete and detailed test plan for field tests of the outside plant including a complete list of test equipment for the copper conductor and optical fiber cables, components, and accessories for approval by the Contracting Officer. Include a cut-over plan with procedures and schedules for relocation of facility station numbers without interrupting service to any active location. Submit the plan at least 30 days prior to tests for Contracting Officer approval. Provide outside plant testing and performance measurement criteria in accordance with TIA-568-C.1 and RUS Bull 1753F-201. Include procedures for certification, validation, and testing that includes fiber optic link performance criteria.

1.6.4 Standard Products

Provide materials and equipment that are standard products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship and shall be the manufacturer's latest standard design that has been in satisfactory commercial or industrial use for at least 2 years prior to bid opening. The 2-year period shall include applications of equipment and materials under similar circumstances and of similar size. The product shall have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period. Products supplied shall be specifically designed and manufactured for use with outside plant telecommunications systems. Where two or more items of the same class of equipment are required, these items shall be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.6.4.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is provided.

1.6.4.2 Material and Equipment Manufacturing Date

Products manufactured more than 3 years prior to date of delivery to site shall not be used, unless specified otherwise.

1.6.5 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Equipment, materials,

installation, and workmanship shall be in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.6.5.1 Independent Testing Organization Certificate

In lieu of the label or listing, submit a certificate from an independent testing organization, competent to perform testing, and approved by the Contracting Officer. The certificate shall state that the item has been tested in accordance with the specified organization's test methods and that the item complies with the specified organization's reference standard.

1.7 DELIVERY, STORAGE, AND HANDLING

Ship cable on reels in with a minimum overage of 10 percent. Radius of the reel drum shall not be smaller than the minimum bend radius of the cable. Wind cable on the reel so that unwinding can be done without kinking the cable. Two meters of cable at both ends of the cable shall be accessible for testing. Attach permanent label on each reel showing length, cable identification number, cable size, cable type, and date of manufacture. Provide water resistant label and the indelible writing on the labels. Apply end seals to each end of the cables to prevent moisture from entering the cable. Reels with cable shall be suitable for outside storage conditions when temperature ranges from minus 40 degrees C to plus 65 degrees C, with relative humidity from 0 to 100 percent. Equipment, other than cable, delivered and placed in storage shall be stored with protection from weather, humidity and temperature variation, dirt and dust, or other contaminants in accordance with manufacturer's requirements.

1.8 MAINTENANCE

1.8.1 Record Documentation

Provide the activity responsible for telecommunications system maintenance and administration a single complete and accurate set of record documentation for the entire telecommunications system with respect to this project.

Provide T5 drawings including documentation on cables and termination hardware in accordance with TIA-606. T5 drawings shall include schedules to show information for cut-overs and cable plant management, patch panel layouts, cross-connect information and connecting terminal layout as a minimum. T5 drawings shall be provided in hard copy format or on electronic media using Windows based computer cable management software. Update existing record documentation to reflect campus distribution T0 drawings and T3 drawing schedule information modified, deleted or added as a result of this installation. Provide the following T5 drawing documentation as a minimum:

- a. Cables - A record of installed cable shall be provided in accordance with TIA-606. The cable records shall include only the required data fields in accordance with TIA-606. Include manufacture date of cable with submittal.
- b. Termination Hardware - Provide a record of installed patch panels, cross-connect points, campus distributor and terminating block arrangements and type in accordance with TIA-606. Documentation shall include only the required data fields in accordance with TIA-606.

Provide record documentation as specified in Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM.

1.9 WARRANTY

The equipment items shall be supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

Products supplied shall be specifically designed and manufactured for use with outside plant telecommunications systems.

2.2 TELECOMMUNICATIONS ENTRANCE FACILITY

2.2.1 Building Protector Assemblies

Provide self-contained 5 pin unit supplied with a field cable stub factory connected to protector socket blocks to terminate and accept protector modules for 50 pairs of outside cable. Building protector assembly shall have interconnecting hardware for connection to interior cabling at full capacity. Provide manufacturers instructions for building protector assembly installation. Provide copper cable interconnecting hardware as specified in Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM.

2.2.2 Protector Modules

Provide in accordance with UL 497 three-electrode gas tube or solid state type 5 pin rated for the application. Provide gas tube protection modules in accordance with RUS Bull 345-83 and shall be heavy duty, $A > 10\text{kA}$, $B > 400$, $C > 65\text{A}$ where A is the maximum single impulse discharge current, B is the impulse life and C is the AC discharge current in accordance with ANSI C62.61. The gas modules shall shunt high voltage to ground, fail short, and be equipped with an external spark gap and heat coils in accordance with UL 497. Provide the number of surge protection modules equal to the number of pairs of exterior cable of the building protector assembly.

2.2.3 Fiber Optic Terminations

Provide fiber optic cable terminations as specified in 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM.

2.3 CLOSURES

2.3.1 Copper Conductor Closures

2.3.1.1 Underground Cable Closures

- a. In vault or manhole: Provide underground closure suitable to house a straight, butt, and branch splice in a protective housing into which can be poured an encapsulating compound. Closure shall be of suitable thermoplastic, thermoset, or stainless steel material supplying structural strength necessary to pass the mechanical and electrical

requirements in a vault or manhole environment. Encapsulating compound shall be reenterable and shall not alter the chemical stability of the closure. Provide filled splice cases in accordance with RUS Bull 345-72.

2.3.2 Fiber Optic Closures

2.3.2.1 In Vault or Manhole

Provide underground closure suitable to house splice organizer in a protective housing into which can be poured an encapsulating compound. Closure shall be of thermoplastic, thermoset, or stainless steel material supplying structural strength necessary to pass the mechanical and electrical requirements in a vault or manhole environment. Encapsulating compound shall be reenterable and shall not alter the chemical stability of the closure.

2.4 CABLE SPLICES, AND CONNECTORS

2.4.1 Copper Cable Splices

Provide multipair splices of a moisture resistant, insulation displacement connector held rigidly in place to assure maximum continuity in accordance with RUS Bull 1753F-401. Cables greater than 25 pairs shall be spliced using multipair splicing connectors, which accommodate 25 pairs of conductors at a time. Provide correct connector size to accommodate the cable gauge of the supplied cable.

2.4.2 Copper Cable Splice Connector

Provide splice connectors with a polycarbonate body and cap and a tin-plated brass contact element. Connector shall accommodate 22 to 26 AWG solid wire with a maximum insulation diameter of 0.065 inch. Fill connector with sealant grease to make a moisture resistant connection, in accordance with RUS Bull 1753F-401.

2.4.3 Fiber Optic Cable Splices

Provide fiber optic cable splices and splicing materials for fusion methods at locations shown on the construction drawings. The splice insertion loss shall be 0.3 dB maximum when measured in accordance with TIA-455-78-B using an Optical Time Domain Reflectometer (OTDR). Splices shall be designed for a return loss of 40.0 db max for single mode fiber when tested in accordance with TIA-455-107. Physically protect each fiber optic splice by a splice kit specially designed for the splice.

2.4.4 Fiber Optic Splice Organizer

Provide splice organizer suitable for housing fiber optic splices in a neat and orderly fashion. Splice organizer shall allow for a minimum of 3 feet of fiber for each fiber within the cable to be neatly stored without kinks or twists. Splice organizer shall accommodate individual strain relief for each splice and allow for future maintenance or modification, without damage to the cable or splices. Provide splice organizer hardware, such as splice trays, protective glass shelves, and shield bond connectors in a splice organizer kit.

2.5 CONDUIT

Provide conduit as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

2.6 PLASTIC INSULATING TAPE

UL 510.

2.7 WIRE AND CABLE

2.7.1 Copper Conductor Cable

Solid copper conductors, covered with an extruded solid insulating compound. Insulated conductors shall be twisted into pairs which are then stranded or oscillated to form a cylindrical core. For special high frequency applications, the cable core shall be separated into compartments. Cable shall be completed by the application of a suitable core wrapping material, a corrugated copper or plastic coated aluminum shield, and an overall extruded jacket. Telecommunications contractor shall verify distances between splice points prior to ordering cable in specific cut lengths. Gauge of conductor shall determine the range of numbers of pairs specified; 19 gauge (6 to 400 pairs), 22 gauge (6 to 1200 pairs), 24 gauge (6 to 2100 pairs), and 26 gauge (6 to 3000 pairs). Copper conductor shall conform to the following:

2.7.1.1 Underground

Provide filled cable meeting the requirements of ICEA S-99-689 and RUS 1755.390 or RUS 1755.890.

2.7.1.2 Screen

Provide screen-compartmental core cable filled cable meeting the requirements of ICEA S-99-689 and RUS 1755.390.

2.7.2 Fiber Optic Cable

Provide single-mode, 8/125-um, 0.10 aperture 1310 nm fiber optic cable in accordance with TIA-492CAAA, TIA-472D000, and ICEA S-87-640 including any special requirements made necessary by a specialized design. Provide optical fibers as indicated. Fiber optic cable shall be specifically designed for outside use with loose buffer construction. Provide fiber optic color code in accordance with TIA/EIA-598

2.7.2.1 Strength Members

Provide central, non-metallic strength members with sufficient tensile strength for installation and residual rated loads to meet the applicable performance requirements in accordance with ICEA S-87-640. The strength member is included to serve as a cable core foundation to reduce strain on the fibers, and shall not serve as a pulling strength member.

2.7.2.2 Performance Requirements

Provide fiber optic cable with optical and mechanical performance requirements in accordance with ICEA S-87-640.

2.7.3 Grounding and Bonding Conductors

Provide grounding and bonding conductors in accordance with RUS 1755.200, TIA-607, IEEE C2, and NFPA 70. Solid bare copper wire meeting the requirements of ASTM B1 for sizes No. 8 AWG and smaller and stranded bare copper wire meeting the requirements of ASTM B8, for sizes No. 6 AWG and larger. Insulated conductors shall have 600-volt, Type TW insulation meeting the requirements of UL 83.

2.8 CABLE TAGS IN MANHOLES, HANDHOLES, AND VAULTS

Provide tags for each telecommunications cable or wire located in manholes, handholes, and vaults. Cable tags shall be stainless steel or polyethylene and labeled in accordance with TIA-606. Handwritten labeling is unacceptable.

2.8.1 Stainless Steel

Provide stainless steel, cable tags 1 5/8 inches in diameter 1/16 inch thick minimum, and circular in shape. Tags shall be die stamped with numbers, letters, and symbols not less than 0.25 inch high and approximately 0.015 inch deep in normal block style.

2.8.2 Polyethylene Cable Tags

Provide tags of polyethylene that have an average tensile strength of 3250 pounds per square inch; and that are 0.08 inch thick (minimum), non-corrosive non-conductive; resistive to acids, alkalis, organic solvents, and salt water; and distortion resistant to 170 degrees F. Provide 0.05 inch (minimum) thick black polyethylene tag holder. Provide a one-piece nylon, self-locking tie at each end of the cable tag. Ties shall have a minimum loop tensile strength of 175 pounds. The cable tags shall have black block letters, numbers, and symbols one inch high on a yellow background. Letters, numbers, and symbols shall not fall off or change positions regardless of the cable tags' orientation.

2.9 BURIED WARNING AND IDENTIFICATION TAPE

Provide fiber optic media marking and protection in accordance with TIA-590. Provide color, type and depth of tape as specified in paragraph BURIED WARNING AND IDENTIFICATION TAPE in Section 31 00 00, EARTHWORK.

2.10 MANUFACTURER'S NAMEPLATE

Each item of equipment shall have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

2.11 FIELD FABRICATED NAMEPLATES

Provide laminated plastic nameplates in accordance with ASTM D709 for each patch panel, protector assembly, rack, cabinet and other equipment or as indicated on the drawings. Each nameplate inscription shall identify the function and, when applicable, the position. Nameplates shall be melamine plastic, 0.125 inch thick, white with black center core. Surface shall be matte finish. Corners shall be square. Accurately align lettering and engrave into the core. Minimum size of nameplates shall be one by 2.5 inches. Lettering shall be a minimum of 0.25 inch high normal block style.

2.12 TESTS, INSPECTIONS, AND VERIFICATIONS

2.12.1 Factory Reel Test Data

Test 100 percent OTDR test of FO media at the factory in accordance with TIA-568-C.1 and TIA-568-C.3. Use TIA-526-7 for single mode fiber and TIA-526-14 Method B for multi mode fiber measurements. Calibrate OTDR to show anomalies of 0.2 dB minimum. Enhanced performance filled OSP copper cables, referred to as Broadband Outside Plant (BBOSP), shall meet the requirements of ICEA S-99-689. Enhanced performance air core OSP copper cables shall meet the requirements of ICEA S-98-688. Submit test reports, including manufacture date for each cable reel and receive approval before delivery of cable to the project site.

PART 3 EXECUTION

3.1 INSTALLATION

Install all system components and appurtenances in accordance with manufacturer's instructions IEEE C2, NFPA 70, and as indicated. Provide all necessary interconnections, services, and adjustments required for a complete and operable telecommunications system.

3.1.1 Contractor Damage

Promptly repair indicated utility lines or systems damaged during site preparation and construction. Damages to lines or systems not indicated, which are caused by Contractor operations, shall be treated as "Changes" under the terms of the Contract Clauses. When Contractor is advised in writing of the location of a nonindicated line or system, such notice shall provide that portion of the line or system with "indicated" status in determining liability for damages. In every event, immediately notify the Contracting Officer of damage.

3.1.2 Cable Inspection and Repair

Handle cable and wire provided in the construction of this project with care. Inspect cable reels for cuts, nicks or other damage. Damaged cable shall be replaced or repaired to the satisfaction of the Contracting Officer. Reel wraps shall remain intact on the reel until the cable is ready for placement.

3.1.3 Underground Duct

Provide underground duct and connections to existing manholes, as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION with any additional requirements as specified herein.

3.1.4 Reconditioning of Surfaces

Provide reconditioning of surfaces as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

3.1.5 Penetrations

Caulk and seal cable access penetrations in walls, ceilings and other parts of the building. Seal openings around electrical penetrations through fire resistance-rated wall, partitions, floors, or ceilings in

accordance with Section 07 84 00 FIRESTOPPING.

3.1.6 Cable Pulling

Test duct lines with a mandrel and swab out to remove foreign material before the pulling of cables. Avoid damage to cables in setting up pulling apparatus or in placing tools or hardware. Do not step on cables when entering or leaving the manhole. Do not place cables in ducts other than those shown without prior written approval of the Contracting Officer. Roll cable reels in the direction indicated by the arrows painted on the reel flanges. Set up cable reels on the same side of the manhole as the conduit section in which the cable is to be placed. Level the reel and bring into proper alignment with the conduit section so that the cable pays off from the top of the reel in a long smooth bend into the duct without twisting. Under no circumstances shall the cable be paid off from the bottom of a reel. Check the equipment set up prior to beginning the cable pulling to avoid an interruption once pulling has started. Use a cable feeder guide of suitable dimensions between cable reel and face of duct to protect cable and guide cable into the duct as it is paid off the reel. As cable is paid off the reel, lubricate and inspect cable for sheath defects. When defects are noticed, stop pulling operations and notify the Contracting Officer to determine required corrective action. Cable pulling shall also be stopped when reel binds or does not pay off freely. Rectify cause of binding before resuming pulling operations. Provide cable lubricants recommended by the cable manufacturer. Avoid bends in cables of small radii and twists that might cause damage. Do not bend cable and wire in a radius less than 10 times the outside diameter of the cable or wire.

3.1.6.1 Cable Tensions

Obtain from the cable manufacturer and provide to the Contracting Officer, the maximum allowable pulling tension. This tension shall not be exceeded.

3.1.6.2 Pulling Eyes

Equip cables 1.25 inches in diameter and larger with cable manufacturer's factory installed pulling-in eyes. Provide cables with diameter smaller than 1.25 inches with heat shrinkable type end caps or seals on cable ends when using cable pulling grips. Rings to prevent grip from slipping shall not be beaten into the cable sheath. Use a swivel of 3/4 inch links between pulling-in eyes or grips and pulling strand.

3.1.6.3 Installation of Cables in Manholes, Handholes, and Vaults

Do not install cables utilizing the shortest route, but route along those walls providing the longest route and the maximum spare cable lengths. Form cables to closely parallel walls, not to interfere with duct entrances, and support cables on brackets and cable insulators at a maximum of 4 feet. In existing manholes, handholes, and vaults where new ducts are to be terminated, or where new cables are to be installed, modify the existing installation of cables, cable supports, and grounding as required with cables arranged and supported as specified for new cables. Identify each cable with corrosion-resistant embossed metal tags.

3.1.7 Cable Splicing

3.1.7.1 Copper Conductor Splices

Perform splicing in accordance with requirements of RUS Bull 1753F-401 except that direct buried splices and twisted and soldered splices are not allowed. Exception does not apply for pairs assigned for carrier application.

3.1.7.2 Fiber Optic Splices

Fiber optic splicing shall be in accordance with manufacturer's recommendation and shall exhibit an insertion loss not greater than 0.2 dB for fusion splices.

3.1.8 Surge Protection

All cables and conductors, except fiber optic cable, which serve as communication lines through off-premise lines, shall have surge protection installed at each end which meet the requirements of RUS Bull 1751F-815.

3.1.9 Grounding

Provide grounding and bonding in accordance with RUS 1755.200, TIA-607, IEEE C2, and NFPA 70. Ground exposed noncurrent carrying metallic parts of telephone equipment, cable sheaths, cable splices, and terminals.

3.1.9.1 Telecommunications Master Ground Bar (TMGB)

The TMGB is the hub of the basic telecommunications grounding system providing a common point of connection for ground from outside cable, CD, and equipment. Establish a TMGB for connection point for cable stub shields to connector blocks and CD protector assemblies as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

3.1.9.2 Incoming Cable Shields

Shields shall not be bonded across the splice to the cable stubs. Ground shields of incoming cables in the EF Telecommunications to the TMGB.

3.1.9.3 Campus Distributor Grounding

- a. Protection assemblies: Mount CD protector assemblies directly on the telecommunications backboard. Connect assemblies mounted on each vertical frame with No. 6 AWG copper conductor to provide a low resistance path to TMGB.
- b. TMGB connection: Connect TMGB to TGB with copper conductor with a total resistance of less than 0.01 ohms.

3.1.10 Cut-Over

All necessary transfers and cut-overs, shall be accomplished by the telecommunications contractor.

3.2 LABELING

3.2.1 Labels

Provide labeling for new cabling and termination hardware located within the facility in accordance with TIA-606. Handwritten labeling is unacceptable. Stenciled lettering for cable and termination hardware shall be provided using thermal ink transfer process or laser printer.

3.2.2 Cable Tag Installation

Install cable tags for each telecommunications cable or wire located in manholes, handholes, and vaults including each splice. Tag only new wire and cable provided by this contract. The labeling of telecommunications cable tag identifiers shall be in accordance with TIA-606. Do not provide handwritten letters. Install cable tags so that they are clearly visible without disturbing any cabling or wiring in the manholes, handholes, and vaults.

3.2.3 Termination Hardware

Label patch panels, distribution panels, connector blocks and protection modules using color coded labels with identifiers in accordance with TIA-606.

3.3 FIELD FABRICATED NAMEPLATE MOUNTING

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

3.4 FIELD QUALITY CONTROL

Provide the Contracting Officer 10 working days notice prior to each test. Provide labor, equipment, and incidentals required for testing. Correct defective material and workmanship disclosed as the results of the tests. Furnish a signed copy of the test results to the Contracting Officer within 3 working days after the tests for each segment of construction are completed. Perform testing as construction progresses and do not wait until all construction is complete before starting field tests.

3.4.1 Pre-Installation Tests

Perform the following tests on cable at the job site before it is removed from the cable reel. For cables with factory installed pulling eyes, these tests shall be performed at the factory and certified test results shall accompany the cable.

3.4.1.1 Cable Capacitance

Perform capacitance tests on at least 10 percent of the pairs within a cable to determine if cable capacitance is within the limits specified.

3.4.1.2 Loop Resistance

Perform DC-loop resistance on at least 10 percent of the pairs within a cable to determine if DC-loop resistance is within the manufacturer's calculated resistance.

3.4.1.3 Pre-Installation Test Results

Provide results of pre-installation tests to the Contracting Officer at least 5 working days before installation is to start. Results shall indicate reel number of the cable, manufacturer, size of cable, pairs tested, and recorded readings. When pre-installation tests indicate that cable does not meet specifications, remove cable from the job site.

3.4.2 Acceptance Tests

Perform acceptance testing in accordance with RUS Bull 1753F-201 and as further specified in this section. Provide personnel, equipment, instrumentation, and supplies necessary to perform required testing. Notification of any planned testing shall be given to the Contracting Officer at least 14 days prior to any test unless specified otherwise. Testing shall not proceed until after the Contractor has received written Contracting Officer's approval of the test plans as specified. Test plans shall define the tests required to ensure that the system meets technical, operational, and performance specifications. The test plans shall define milestones for the tests, equipment, personnel, facilities, and supplies required. The test plans shall identify the capabilities and functions to be tested. Provide test reports in booklet form showing all field tests performed, upon completion and testing of the installed system. Measurements shall be tabulated on a pair by pair or strand by strand basis.

3.4.2.1 Copper Conductor Cable

Perform the following acceptance tests in accordance with TIA-758:

- a. Wire map (pin to pin continuity)
- b. Continuity to remote end
- c. Crossed pairs
- d. Reversed pairs
- e. Split pairs
- f. Shorts between two or more conductors

3.4.2.2 Fiber Optic Cable

Test fiber optic cable in accordance with TIA/EIA-455 and as further specified in this section. Two optical tests shall be performed on all optical fibers: Optical Time Domain Reflectometry (OTDR) Test, and Attenuation Test. In addition, a Bandwidth Test shall be performed on all multimode optical fibers. These tests shall be performed on the completed end-to-end spans which include the near-end pre-connectorized single fiber cable assembly, outside plant as specified, and the far-end pre-connectorized single fiber cable assembly.

- a. OTDR Test: The OTDR test shall be used to determine the adequacy of the cable installations by showing any irregularities, such as discontinuities, micro-bendings or improper splices for the cable span under test. Hard copy fiber signature records shall be obtained from

the OTDR for each fiber in each span and shall be included in the test results. The OTDR test shall be measured in both directions. A reference length of fiber, 66 feet minimum, used as the delay line shall be placed before the new end connector and after the far end patch panel connectors for inspection of connector signature. Conduct OTDR test and provide calculation or interpretation of results in accordance with TIA-526-7 for single-mode fiber and TIA-526-14 for multimode fiber. Splice losses shall not exceed 0.3 db.

- b. Attenuation Test: End-to-end attenuation measurements shall be made on all fibers, in both directions, using a 1310 nanometer light source at one end and the optical power meter on the other end to verify that the cable system attenuation requirements are met in accordance with TIA-526-7 for single-mode fiber optic cables. The measurement method shall be in accordance with TIA-455-78-B. Attenuation losses shall not exceed 0.5 db/km at 1310 nm and 1550 nm for single-mode fiber.
- c. Bandwidth Test: The end-to-end bandwidth of all multimode fiber span links shall be measured by the frequency domain method. The bandwidth shall be measured in both directions on all fibers. The bandwidth measurements shall be in accordance with TIA/EIA-455-204.

-- End of Section --

SECTION 46 25 14

COALESCING OIL-WATER SEPARATORS
02/11, CHG 1: 11/13

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B16.5 (2020) Pipe Flanges and Flanged Fittings
NPS 1/2 Through NPS 24 Metric/Inch Standard

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA 10084 (2017) Standard Methods for the
Examination of Water and Wastewater

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M (2020; Errata 1 2021) Structural Welding
Code - Steel

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M (2019) Standard Specification for Carbon
Structural Steel

ASTM C990 (2009; R 2019) Standard Specification for
Joints for Concrete Pipe, Manholes, and
Precast Box Sections Using Preformed
Flexible Joint Sealants

ASTM E165/E165M (2018) Standard Practice for Liquid
Penetrant Examination for General Industry

SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC SP 10/NACE No. 2 (2007) Near-White Blast Cleaning

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-DTL-24441 (2009; Rev D; Notice 1 2021) Paint,
Epoxy-Polyamide, General Specification for

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA 600/4-79/020 (1983) Methods for Chemical Analysis of
Water and Wastes

1.2 SYSTEM DESCRIPTION

1.2.1 Applications

The 6,000 gallon cylindrical underground double-wall oil water separator shall remove free oil and suspended solids from oil-in-water mixtures of freshwater originating from aircraft operations. The influent oil-in-water mixture will flow by gravity to the unit which will not be located in an area with a corrosive atmosphere.

1.2.2 Influent Characteristics

Provide oil-water separator designed for a maximum flow of 600 gallons per minute. Operating temperatures of the influent oil-in-water mixture will range from 40 to 80 degrees F and ambient air temperatures will range from 0 to 95 degrees F. The specific gravity of the oil at operating oil-water temperatures will range from 0.71 to 0.92. The specific gravity of the freshwater at operating temperatures will range from 1.00 to 1.03. 1.2.3 Performance Requirements

The free oil and petroleum hydrocarbon concentration in the effluent from the oil-water separator shall not exceed 10 mg/L (10 ppm).

To achieve this goal, it will be necessary to remove all free oil droplets equal to or greater than 20 microns.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" classification. Submittals not having a "G" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

Separator; GSD-06 Test Reports

Shop hydrostatic test; G

Submit results of hydrostatic and dynamic testing.

Inspection

Field hydrostatic test

Preoperational test

In-service test

SD-07 Certificates

Separator corrosion protection; G

Submit written verification on the fabricator's letterhead that surface preparation and coating application were performed in accordance with the manufacturer's printed recommendations for the coating system.

SD-08 Manufacturer's Instructions

Separator System; G

SD-10 Operation and Maintenance Data

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

1.4 DELIVERY, STORAGE, AND HANDLING

1.4.1 Delivery and Storage

Inspect materials delivered to site for damage; unload and store with minimum handling. Store materials on-site in enclosures or under protective coverings. Protect materials not suitable for outdoor storage to prevent damage during periods of inclement weather, such as subfreezing temperatures, precipitation, and high winds. Store materials susceptible to deterioration by direct sunlight under cover and avoid damage due to high temperatures. Do not store materials directly on ground. If special precautions are required, prominently and legibly stencil instructions for such precautions on outside of equipment or its crating.

1.4.2 Handling

Handle separator in such a manner as to ensure delivery to final location in sound, undamaged condition. Take special care not to damage interior and exterior surfaces of separator, coalescing plates, and associated supports and pipe coatings or linings. Make satisfactory repairs to damaged materials at no cost to Government. Carry and do not drag materials.

PART 2 PRODUCTS

2.1 MATERIALS

Use 3/16 inch minimum thick carbon steel conforming to ASTM A36/A36M or material having equivalent structural properties and corrosion resistance for separator, hoppers, stationary and adjustable weirs, nozzles, flow distributor and energy dissipator device, bolts, seals, stiffeners, washers, separator cover and nuts. Weld in accordance with AWS D1.1/D1.1M to provide watertight separator that will not warp or deform under load. Use welders qualified in accordance with AWS Standard Qualification Procedure. Grind welds smooth and remove weld spatter. Fabricate free of kinks and sharp bends in a manner not to reduce the strength of steel to a value less than that intended by the design. Size and shape of bends shall be uniform. Clean and finish carbon steel surfaces as described in paragraph entitled "Separator Corrosion Protection."

2.1.1 Separator Corrosion Protection

2.1.1.1 Steel Separator

After shop conducted hydrostatic tests have been successfully completed, provide a MIL-DTL-24441 coating system to the interior and exterior surfaces of the separator. Prior to shop painting, abrasive blast clean the surfaces in accordance with SSPC SP 10/NACE No. 2 to a surface profile of 1 to 2 1/2 mils. Apply primer conforming to MIL-DTL-24441/1, Formula 150 applied to a minimum dry film thickness of 3 to 4 mils. Apply intermediate coat conforming to MIL-DTL-24441/2, Formula 151 applied to a minimum dry film thickness of 3 to 4 mils. Apply topcoat conforming to MIL-DTL-24441/3, Formula 152 applied to a minimum dry film thickness of 3

to 4 mils. Total dry film thickness shall not be less than 9 mils. Repair and replace areas of the coating system which are found to be damaged or defective upon delivery of equipment to the site or found to be defective due to work of the applicator. An interior polytetrafluoroethylene liner with a minimum thickness of 1/8 inch may be provided in lieu of paint coating the interior separator surfaces.

2.1.1.2 Other Than Steel Separator

After shop conducted hydrostatic tests and have been successfully completed, provide a coating system which will protect the separator from the oil-in-water mixture, and in situ soil conditions specified herein.

2.1.1.3 Cathodic Protection

For below ground metal separators, provide cathodic protection with test stations as specified in Section 26 42 13 GALVANIC (SACRIFICIAL) ANODE CATHODIC PROTECTION (GACP) SYSTEM in addition to the protective coating.

2.1.2 Substitutions

Substitutions must be approved by the Engineer.

2.1.3 External Surfaces

External surfaces and appurtenances shall be resistant to corrosion from the in situ soil, backfill material, groundwater, and soil pH.

2.1.4 Internal Surfaces

Parallel plate material and orientation shall enhance oil coalescence and solids removal, and be corrosion and chemically resistant to the oil-in-water mixture as specified in paragraph entitled "SYSTEM DESCRIPTION."

2.1.5 Hardware

Bolts, stiffeners, washers, nuts, screws, pins, and fittings as required shall be corrosion resistant. Provide materials that are inherently corrosion resistant and not merely treated with a corrosion-resistant coating, such as provided by the galvanizing process.

2.1.6 Accessibility

Separators below grade shall have a minimum of two 23-inch diameter manways for access. As a minimum provide access hatches over the following areas: parallel plates, oil storage compartments, Influent sampling area, effluent sampling area, oil skimmer, and weirs. Parts subject to wear or requiring adjustment, inspection, cleaning or repair shall be accessible and capable of convenient removal when required.

2.2 SEPARATION CHAMBER

Provide below ground separator to withstand hydraulic and soil loadings under static and dynamic conditions while empty and during operating conditions. Provide adequate support for additional loadings from separator appurtenances including weirs, hoppers, internal supports, parallel plate oil coalescers, equipment transportation, and rapid lowering and braking of load during handling operations. Bolt separator

and accessories to weld-fabricated, structural steel skid base, or mount on manufacturer's standard base.

2.2.1 Lifting Mechanism

Fit separator with lifting lugs for handling and installation. Each lug shall carry the total dry weight of the separator and attendant appurtenances. Prominently display lifting instructions on plate located on outside of separator.

2.2.2 Flanges

Use only flat face flanges and drill 150 pound ANSI Standard bolt circle and remove burrs. Use flanged piping connections that conform to ASME B16.5, welding neck type.

2.2.3 Identification Plates

Provide anodized aluminum identification and instruction plates and stamp necessary data. Securely affix plates, in prominent location, to separator with nonferrous screws or bolts of not less than 1/8 inch in diameter.

2.2.4 Instruction Plates

Instruction plates shall describe special or required procedures to operate and service equipment, and shall include warnings of hazardous procedures and notice of safety and health requirements. Plates shall be durable and legible throughout equipment life.

2.2.5 Warning Sign

On entrances to the separator a permanent sign which states the following: "DO NOT ENTER separator OR PERFORM HOT WORK ON OR IN separator UNTIL THE ATMOSPHERE HAS BEEN TESTED AND CERTIFIED GAS FREE AND SAFE."

2.3 INLET COMPARTMENT

Provide inlet compartment of sufficient volume to effectively reduce influent settleable solids and dissipate energy.

2.4 OIL SEPARATION COMPARTMENT

2.4.1 General

Detention time will recomputed by calculating the volume of the separation zone within the separator and dividing this volume by the design flow rate. For computing detention time, total volume shall be reduced by 20 percent for the space occupied by settled solids and accumulated oil at the surface.

2.4.2 Parallel Plates

Provide parallel plates at an angle from 40 to 60 degrees with respect to longitudinal axis of the plate corrugations and space not less than 3/4 inch apart for removal of free oil and settleable solids. Configuration used shall not promote solids buildup on plates which would increase velocities to point of discharging an effluent of unacceptable quality. Maintain laminar flow at maximum design flow rate throughout plate packs

including entrance and exit so as to prevent re-entrainment of oil(s) with water. Flow through plate packs shall be in a downflow mode parallel to plate corrugations or cross-flow perpendicular to plate corrugations, so that the oil collects and coalesces at high point of corrugations and rises to top of pack without clogging from oil or settleable solids.

2.5 ACCESSORIES

Provide bolts, stiffeners, washers, nuts, screws, pins, gaskets, and fittings as required for separator covers and parallel plate packs.

2.6 FABRICATION

Provide shop fabricated, skid mounted oil-water separator, or other shop fabricated unit approved by the Contracting Officer, which is comprised of a separator containing an inlet compartment, parallel plate oil coalescing compartment.

2.6.1 Shop Hydrostatic Test

Prior to applying coatings, perform hydrostatic test at atmospheric pressure by filling separator with water in the shop for a minimum of 4 hours. Testing shall be conducted after all seams have been cleaned and all welds have been inspected in accordance with ASTM E165/E165M. Acceptance criteria, for the hydrostatic test, is no leakage after 4 hours using a thorough visual inspection for the leaks.

2.6.2 Reduction of Solids

Inlet compartment shall reduce settleable solids to nonclogging level for parallel plates and provide a uniform oily wastewater hydraulic loading across inlet face of oil coalescing compartment, under laminar flow conditions.

2.6.3 Oil Coalescing Compartment

Equip oil coalescing compartment with easily removable and reinstallable, parallel, corrugated plates arranged to optimize separation of free oil from liquid carrier. Use parallel plates that are easily removable without dismantling packs and without confined space entry. Provide adjustable surface oil overflow weir with trough, oil outlet nozzle and stationary underflow baffle, oil retention baffle positioned to prevent discharge of free oil that has been separated from the carrier liquid in inlet and oil coalescing compartments. Provide access to each plate pack from top. Each bundle shall be equipped with handles or lifting rings. Plate designs that permit cleaning of plate packs in place are not acceptable.

2.6.4 Wastewater Sampling Port

Equip inlet and outlet compartments, adjustable overflow effluent weir, effluent trough, and wastewater outlet nozzle with wastewater sampling ports permitting easy access for obtaining isokinetic influent and effluent samples.

2.6.5 Connections

Connect the separator at the inlet and outlet pipe invert elevations indicated. Follow equipment manufacturer's recommendation for setting and

adjusting top of weir elevations throughout unit.

2.6.6 Storage

Provide oil and suspended solids collection, storage, and transfer systems as an integral part of proposed oil-water separator system. As a minimum, the separator oil storage compartment shall have a capacity of not less than 10 percent of the total separator volume.

PART 3 EXECUTION

3.1 INSPECTION

Inspect each component of separator for compliance with requirements specified in PART 2 PRODUCTS. Redesign or modification of equipment to comply with specified requirements, or necessary redesign or modification following failure to meet specified requirements, shall receive particular attention for adequacy and suitability. This element of inspection shall encompass visual examinations and dimensional measurements. Noncompliance with specified requirements, or presence of one or more defects preventing or lessening maximum efficiency of separator operation, shall constitute cause for rejection.

3.2 INSTALLATION

Lift separator as required without parallel plate packs in place onto level foundation using lifting mechanism provided. Level separator and bolt to supports to prevent hydrostatic uplift and ensure unit stability. Use a lifting bar through lugs to insert plate packs into separator and place on supports. Caulk around packs and pack supports with sealing compound conforming to ASTM C990 to prevent hydraulic short-circuiting. Avoid abrupt contact between the packs and the separator walls and pack supports to avoid damage. Separator system installation shall be conducted in accordance with manufacturer's recommendations.

3.3 FIELD QUALITY CONTROL

3.3.1 Field Hydrostatic Test

After separator has been leveled and secured to foundation and parallel plate packs are in place, level effluent overflow weir at elevation specified by manufacturer and hydrostatically test unit at atmospheric or operational pressure (for no leakage) for an additional 8 hours by filling with water. Perform the hydrostatic test prior to backfilling below ground or partially below ground installations.

3.3.2 Preoperational Test

The manufacturer's service representative shall inspect, operate, and test unit before in-service testing by the Contractor.

3.3.2.1 Tests

Tests shall include but not be limited to the following:

- a. Soundness (without cracked or otherwise damaged parts).
- b. Completeness in all details, as specified.

- c. Correctness of setting, alignment, and relative arrangement of each component.
- d. Verification of proper operation for all system components.

3.3.2.2 Preoperational Investigation and Test Report

Submit manufacturer's service representative's preoperational test report. Document inspections, operations, adjustments, and tests performed and indicate whether they were acceptable or not. For unacceptable items, describe corrective action taken or recommended. Include detailed descriptions of points inspected, tests and adjustments made, quantitative results obtained if such are specified, and suggestions for precautions to be taken to ensure proper maintenance. Include the manufacturer's certificate that equipment conforms to specified requirements and is ready for permanent operation and that nothing in installation will render manufacturer's warranty null and void.

3.3.3 In-Service Test

After hydrostatic test and preoperational test have been successfully completed and unit has been properly connected to influent and effluent piping, allow influent oil-in-water mixture previously described in paragraph entitled "SYSTEM DESCRIPTION" to flow into separator filled with water. Adjust and level surface oil overflow weirs to optimize oil skimming and minimize water overflow to oil recovery. Optimize operation of unit within 5 working days. Operate unit for a minimum of ten separator volume changes prior to testing for removal of contaminants and document testing results.

3.3.3.1 Analytical Methods

Test and sample preservation methods for test contaminants shall be in accordance with the latest revisions of AWWA 10084, APHA Standard Methods for the Examination of Water and Wastewater, EPA 600/4-79/020, EPA Methods for Chemical Analysis of Water and Wastes, or those substitute methods approved by the governing regulatory agencies having jurisdiction.

3.3.3.2 Test for Contaminants

Verify the separator efficiency by testing influent and effluent for contaminants described in paragraph entitled "Performance Requirements." If effluent quality is found to be unacceptable, then verify influent to effluent performance in particle size removal at the site. Tests shall be performed by an independent certified testing laboratory.

3.3.3.3 Acceptance Criteria

90 percent of the effluent samples taken shall not exceed the specified daily maximum limit for grease and oil contaminants. If the separator does not meet requirements of this specification, due to poor workmanship and wrong fabrication dimensions, the unit may be rejected. If the unit is not operating at design efficiency 5 days after installation, Government may reject system. In the event Government rejects unit, Contractor shall remove separator or defective components and replace with acceptable unit or components and test as specified above.

-- End of Section --

CONTRACT PROGRESS SCHEDULE
 (See Contractor's Instructions on Reverse)

Form Approved
 OMB NO. 0704-0188

Public reporting burden for this collection of information is estimated to average 15 minutes per response. Including the time for reviewing instructions, searching existing data sources, gathering maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department Defense of Washington Headquarters Services, Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project 0704-0188. Washington DC 20503. Please DO NOT RETURN your (form questionnaire) to either of these addresses. Send your completed (form questionnaire) to: SAF AQCO. Washington DC 20330-1000.

1. CONTRACT NO.		8. PROJECT TITLE BASEWIDE UTILITY MONITORING				10. APPROVAL RECOMMENDED BY:		
2. STARTING DATE		9. SUBMITTED BY: Wade E Sand			DATE SIGNED	INSTALLATIONS ENGINEERS'S SIGNATURE		
3. COMPLETION DATE		DATE SIGNED	CONTRACTOR'S NAME (Last, First, Middle Initial) ADDRESS (Street, City, State, Zip Code)		CONTRACTOR'S SIGNATURE		11. APPROVED BY:	
4. PURCHASE REQUEST NO.								
5. PROJECT NO.								
6. ACTUAL STARTING DATE								
7. ACTUAL COMPETION DATE								

LINE NO. A	WORK ELEMENTS B	% C	1-Nov												TOTALS		
			D	E	F	G	H	I	J	K	L						
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INSTRUCTIONS TO CONTRACTORS

1. Prepare three copies of AF Form 3064, in accordance with these instructions and submit to the contracting officer at the time stated in the contract or as established by the contracting officer.
2. Blocks 1,2, and 3. Enter the contract number, starting date, and completion date as shown on the contract.
3. Block 8. Enter the title of the project as shown on the contract.
4. Block 9. Enter the name and address of your firm. The three copies submitted to the contracting officer must be dated and signed by the contractor or an authorized representative of the firm.
5. Lines 1 through 16. Major elements of work (whether unit price or lump sum contract) such as excavation, concrete work, carpentry, engineering, installation of communication electronic facilities, etc., will be shown in Column B in logical sequence and in sufficient detail to identify the element.
6. The percentage of each listed work element to the complete job will be shown opposite each element in Column C. As an example, if 3 work elements are shown: excavation, concrete work, and backfill, and it is estimated that excavation is 50% of the total job, concrete 30%, and backfill 20%, these percentages will be shown opposite each element. The total must equal 100%.
7. Columns D through Q will be used to show planned periodic progress, as required by the contracting officer, during the period of the contract. Only the top half of the space under these columns will be used by contractors. Using the example cited above and assuming that the contract period for performance is 8 weeks, and it is planned to accomplish 10% of the excavation work the 1st week and 20% each week until excavation is complete, 10 would be shown in the upper half of Line 1 under Column D, 20 under Column E and 20 under Column F for a total of 50%. If it is planned to accomplish the concrete work during the 4th, 5th, and 6th weeks in equal amounts, 10 would be entered under columns G, H, and I on Line 2. Assuming the backfill will be accomplished during the 7th and 8th weeks, 10 would be entered under Columns J and K on Line 3. If the contract extends beyond 14 weeks, additional copies of AF Form 3064, with appropriate alterations, may be spliced on as a continuation of performance record.
8. Total amount or work planned at intervals as shown in Columns D through Q will be totaled and entered in the top half of the space under the appropriate column on Line 16. Again, using the example cited above, the totals under Column D through K would read 10, 20, 20, 10, 10, 10, 10, 10, for a total of 100%. These totals will be used to plot an overlay graph using Lines 67 through 15, beginning with Column D and extending to the right that number of columns (weeks) authorized by the contract for performance time.
9. Beginning at the lower left corner, Line 15, Column D, the graph will be plotted using a broken or dotted line showing the cumulative total progress for planned intervals. Again, using the example cited above, the dotted line would, for the 1st week, extend from Line 15 to Line 14 under Column D for 10%. The second week the dotted line would extend from Line 14 to Line 12 under Column E for 20%, making a cumulative total of 30%. The dotted line should end (100%) at the intersection of Line 5 and Column K.
10. In the event the contract is modified by the contracting officer under terms of the contract, changing the progress of work as originally scheduled, adding or deleting work or changing the original completion date, a revised progress schedule will be prepared and submitted to the contracting officer for approval. In preparing the revised schedule, the amount of work completed will be considered, together with the changed new completion date set forth in the contract modification. Considering these factors, the work under the contract will be rescheduled over the new total performance time in the same. The new completion date will be entered in Block 3. "First Revised Schedule," "Second Revised Schedule," etc., will be entered immediately underneath the form title. Time of submission of the revised schedule will be determined by the contracting officer.
11. At such, intervals as may be established by the contracting officer, the contractor will submit to the contracting officer AF Form 3065 "Contract Progress Report," indicating the percentage of work accomplished for each work element during the established reporting period. Accurate reports are of the utmost importance to the contractor and th the Government, since the percentage of completion, or progress, thus reported is used in administration of the contract and maybe used in connection with approval of partial payments under the contract. Care should be taken to plan the work in such manner that it can be accomplished as stated in this schedule. If for any reason it becomes known that any part of the progress under this contract will be delayed, this fact should be reported to the contracting officer immediately.

CONTRACT PROGRESS REPORT

CONTRACTOR		ADDRESS		
REPORT	PERIOD COVERED	PROJECT NO.	CONTRACT NO.	COMPLETION DATE
LINE NO.	WORK ELEMENT	% OF TOTAL JOB	% COMPLETED THIS PERIOD	% COMPLETED CUMULATIVE
1				
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17				
18				
19				
TOTAL				

REMARKS

At the Contracting Officer's discretion and according to the payments clause of the contract, the information provided on this form may be used for computing progress payments.

PROGRESS OR COMPLETION CERTIFICATE

I hereby certify that the contractor has satisfactorily completed the indicated percentage of the contract per contract specifications.

SUBMITTED BY BASE CIVIL ENGINEER'S OFFICE

NAME AND TITLE	SIGNATURE	DATE
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REVIEWED BY OR FOR CONTRACTING OFFICER

NAME AND TITLE	SIGNATURE	DATE
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MATERIAL APPROVAL SUBMITTAL

(See Instructions on Reverse)

*Form Approved
OMB No 9000-0062
Expires May 31, 2005*

Public reporting burden for this collection of information is estimated to average 20 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to the Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project OMB No 9000-0062, Washington DC 20503. Please DO NOT RETURN your form to either of these addresses. Send your completed form to: SAF/AQCP, 1060 Air Force Pentagon, Washington DC 20330

TO: <i>(Contracting Officer)</i>	FROM: <i>(Contractor)</i>	DATE (YYYYMMDD)
CONTRACT NUMBER	SUBMISSION NUMBER	SUBMITTAL <input type="checkbox"/> NEW <input type="checkbox"/> RESUBMITTAL
PREVIOUS SUBMISSION NUMBER	PROJECT NUMBER	

TO BE COMPLETED BY CONTRACTOR			FOR GOVERNMENT USE ONLY			
ITEM NO.	SPECIFICATION SECTION/ PARA NO./DRAWING NO.	DESCRIPTION OF MATERIAL <i>(Include Type, Model Number, Catalog Number, Mfg., etc.)</i>	AP- PROVED	DISAP- PROVED	SEE REVERSE	INITIAL
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
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			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

BY COMPLETING THIS FORM, THE UNDERSIGNED CONTRACTOR CERTIFIES THAT THE MATERIAL COMPLIES WITH ALL SPECIFICATIONS OF SUBJECT CONTRACT.

DATE (YYYYMMDD)	TYPE OR PRINT NAME AND TITLE	SIGNATURE
-----------------	------------------------------	-----------

FOR GOVERNMENT USE ONLY

TO: *(Base Civil Engineering Officer)*

For Evaluation and Action

DATE (YYYYMMDD)	TYPE OR PRINT NAME AND GRADE	SIGNATURE
-----------------	------------------------------	-----------

TO: *(AF Contracting Office)*

RECOMMEND APPROVAL DISAPPROVAL AS INDICATED ABOVE AND SUBJECT TO ANY APPLICABLE COMMENTS ON THE REVERSE

DATE (YYYYMMDD)	TYPE OR PRINT NAME AND GRADE	SIGNATURE
-----------------	------------------------------	-----------

TO: *(Contractor)*

APPROVED DISAPPROVED AS INDICATED ABOVE AND SUBJECT TO ANY APPLICABLE COMMENTS ON THE REVERSE SIDE. REQUEST RESUBMITTAL ON DISAPPROVED ITEMS WITHIN _____ DAYS OF DATE SHOWN BELOW.

DATE (YYYYMMDD)	TYPE OR PRINT NAME AND GRADE	SIGNATURE
-----------------	------------------------------	-----------

COMMENTS

(Number to correspond with applicable Item Number on reverse)

INSTRUCTIONS TO CONTRACTORS

- 1. The term "material" is defined as articles, supplies, raw materials, equipment, parts, components, and end items that are to be incorporated into the work required by the contract.*

- 2. This form is to be used by contractors for submitting Shop Drawings, Equipment Data, Manufacturer's Literature and Certificates and samples of Materials to the Government for approval in accordance with the provisions of this contract. Unless otherwise specified, it is to be prepared in 4 copies, signed, and provided to the contracting officer with appropriate attachments.*

- 3. Item(s) to be approved will be clearly tabbed or identified. Data pertaining to item(s) to be approved will be clearly identified or tabbed, particularly where documents are voluminous, in order to properly evaluate the materials or articles to be incorporated in the work. Each attachment will be numbered to correspond with the item number shown on the face of this form.*

- 4. Requests submitted shall be numbered consecutively, by contract, in the space entitled "Submission No.". This number, in addition to the Contract No., will be used to identify each Material Approval Submittal. Resubmissions will be indicated in the appropriate block and the insertion of previous submission number and data in addition to a new submission number. A single submission should be used for all work of a section of the specifications, but in NO instance should the submission include work for more than one (1) contract. Submittals requiring priority handling will be submitted by separate submittal using the form and so marked across the face of the form.*

- 5. This Material Approval Submittal is not valid unless it is signed by the contracting officer. This approval is required as called for by the contracting officer under the terms of this contract.*

BASE CIVIL ENGINEERING WORK CLEARANCE REQUEST

DATE PREPARED _____

1. PROJECT NO.: _____ LOCATION: _____
 W.O./J.O. NO.: _____ CONTRACT NO.: _____
 DESCRIPTION OF WORK: _____

2. TYPE OF FACILITY/WORK INVOLVED

	A. PAVEMENTS		B. DRAINAGE SYSTEMS		C. RAILROAD TRACKS		D. FIRE DETECTION AND PROTECTION SYSTEMS		E. UTILITY ___ OVERHEAD ___ UNDERGROUND
	F. COMM ___ OVERHEAD ___ UNDERGROUND		G. AIRCRAFT OR VEHICULAR TRAFFIC FLOW		H. SECURITY		I. OTHER (Specify)		

3. INSTRUCTIONS: The BCE work clearance request is used for any work (contract or in house) that may disrupt aircraft or vehicular traffic flow, base utility services, protection provided by fire and intrusion alarm systems, or routine activities of the installation. This form is used to coordinate the required work with key base activities and keep customer inconvenience to a minimum. It is also used to identify potentially hazardous work conditions in an attempt to prevent accidents. The work clearance request is processed just prior to the start of work. If delays are encountered and the conditions at the job site change (or may have changed), this work clearance request must be reprocessed.

4. DATE CLEARANCE REQUIRED	5. DATE CLEARANCE TERMINATED	
6. REQUESTING OFFICIAL (Signature)	7. PHONE NO.	8. ORGANIZATION

CLEARANCE REVIEW

9.	ORGANIZATION	REMARKS	REVIEWER
OFF-BASE ORGANIZATIONS	A. Electric Utility		
	B. Gas Utility		
	C. Water Department		
	D.		
	E. Federal Aviation Administration		
BASE CIVIL ENGINEERING	F. Drainage Systems		
	G. Pavements, Grounds, Railroads		
	H. Water Distribution		
	I. Environmental Impact		
	J. Cathodic Protection		
	K. Sanitary Sewers		
OTHER ON-BASE ORGANIZATIONS	L. Security Police		
	M. Safety		
	N. Communications		
	O. Base Operations		
	P. Fire Department		
	Q. Other (Specify)		

10. REMARKS _____

REQUESTED CLEARANCE _____ APPROVED _____ DISAPPROVED

DATE _____ SIGNATURE OF PROJECT MANAGER _____

Contractor HAZMAT Approval Form

Item No.	Specific Process and Amount brought on Base	Description of Material (Include Manufacture, Material Use For, etc.)	For Government Use Only			
			Approved	Disapproved	See Reverse	Initial

BY COMPLETING THIS FORM, THE UNDERSIGNED CONTRACTOR CERTIFIES THAT THE MATERIAL COMPLIES WITH ALL SPECIFICATIONS OF SUBJECT CONTRACT.

Date (YYYYMMDD)	Type or Print Name and Title	Signature
-----------------	------------------------------	-----------

FOR GOVERNMENT USE ONLY

TO: (Base Safety Office) Reviewed

Date (YYYYMMDD)	Type or Print Name and Grade	Signature
-----------------	------------------------------	-----------

TO: (Base HAZMART Pharmacy) Reviewed

Date (YYYYMMDD)	Type or Print Name and Grade	Signature
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TO: (Base Bioenvironmental Engineering) Reviewed

Date (YYYYMMDD)	Type or Print Name and Grade	Signature
-----------------	------------------------------	-----------

TO: (Base Environmental Engineer)

RECOMMEND <input type="checkbox"/> Approval <input type="checkbox"/> Disapproval as indicated above and subject to any applicable comments on the reverse.	
Date (YYYYMMDD)	Type or Print Name and Grade
	Signature

TO: (Contractor)

TO: (Base Contracting Office Representative)

Approved

Disapproval as indicated above and subject to any applicable comments on the reverse side. Request Resubmittal on Disapproved Items within _____ Days of Date shown below.

Date (YYYYMMDD)

Type or Print Name and Grade

Signature

COMMENTS

(Number to correspond with applicable Item Number on reverse)

INSTRUCTIONS TO CONTRACTORS

- 1 - This form is to be used by contractors for submitting Hazardous Materials that will be used or consumed on a project by both the GM Contractor and all subcontractors
- 2 - Administrative Data: TO: is the Contracting Office Representative (COR) for the project, FROM: is the name of the company contracted, Date is the date submitted to the COR, Submission number is the number of times this form has been submitted for the contract, Contract Number is the number given to the contract, Previous Submission Number shows the prior submission number, Project Number is a LUXC XXXXX number given to the project, Submittal type is either New/Resubmittal/Closeout
- 3 - Material data starts with: Item Number this is the number given to each hazardous material either stored on Base or consumed by the project, Specific Process and Amount brought on Base is the contractors estimate of the amount of hazardous materials that will either be stored on base or consumed during the execution of the project, Description of Material this should include the product name and general description as well as how the product is being used.
- 4 - SDS are required of all materials listed on this form. Item(s) to be approved will be clearly labbed or identified. Data pertaining to item(s) to be approved will be clearly identified or labbed, particularly where documents are voluminous, in order to properly evaluate the materials or articles to be incorporated in the work. Each attachment will be numbered to correspond with the item number shown on the face of this form.
- 5 - Requests submitted shall be numbered consecutively, by contract, in the space entitled "Submission No.". This number, in addition to the Contract No., will be used to identify each Material Approval Submittal. Resubmissions will be indicated in the appropriate block and the insertion of previous submission number and data in addition to a new submission number. A single submission should be used for all work of a section of the specifications, but in NO instance should the submission include work for more than one (1) contract. Submittals requiring priority handling will be submitted by separate submittal using the form and so marked across the face of the form.
- 6 - This Contractor HAZMAT Approval Form is not valid unless it is signed by the COR. This approval is required as called for by the contracting officer under the terms of this contract.

Contractor Hazardous Materials Usage Tracking Form (Return this form to Contracting/Project Manager)

Contractor Name _____ Date of Report _____ Reporting Period _____

Contractor Project Manager _____

Contractor POC for obtaining Hazardous Materials information Name: _____ Phone: _____

Email: _____ Contract# _____ Project # _____

Item No:	Material / Manufacturer:	Material Used For:	Initial Amount on Site	Size of Container	Total Additional Brought on Site	Total Quantity Used	Monthly Remainder
EX	Example: Material: SHERWIN WILLIAMS - PROMAR 400 Interior Latex Semi-Gloss Enamel, Extra White	Painting Building 13, Office 102 & 106	3	1 Gal.	2	4 Gal.	1 Gal.

Contractor HAZMAT Usage Tracking Form

This form is a reflection of the Contractor HAZMAT Approval Form

Contractors are responsible for all Sub Contractors utilized for the project number listed on the form

- **Contractor Name:** Name of the contracting company
- **Date of Report:** Date the contractor is submitting this form ex: 5 May 2016
- **Reporting Period:** The month of the project that this form is for ex: 1 May 2016 – 31 May 2016
- **Contractor Project Manager:** The contractor's on site project manager or person responsible for submitting this form
- **Contractor POC for obtaining Hazardous Materials Information Name:** Only need if different than the Contractor Project Manager
- **Phone:** Phone number of the contractor's on site project manager or person responsible for submitting this form
- **Email:** Email of the contractor's on site project manager or person responsible for submitting this form
- **Contract #:** the contract number for this contract
- **Project #:** the project number for this contract
- **Item Number:** will match the Item Number from the Approval Form (If there is no usage on an Item Number that was previously approved on the Contractor HAZMAT Approval Form do not list that item number)
- **Material / Manufacturer:** will match the manufacturer and description of material on the Approval Form
- **Material Used For:** box will describe how that material is being consumed on Base
- **Initial Amount on Site:** will match the estimate on the Approval Form for amount brought on Base
- **Size of Container:** reflects the size of container by a specific unit of measurement that the material is stored in while on Base
- **Total Additional Brought on Site:** this number is the total number of additional container sizes brought on base such as in the example shows that 2 additional 1 gallon containers were brought on Base giving us a total of 5 gallons on Base.
 - If the amount brought on site is labeled with a unit of measurement then it will not be assumed to be the same size as the container
- **Total Quantity Used:** Shows the amount of chemical by a specific unit of measurement used during the reporting period
- **Monthly Remainder:** Shows the amount of chemical remaining on site by a specific unit of measurement

EQUIPMENT/WARRANTY SUMMARY

BUILDING NO: _____ **PROJECT MANAGER:** _____

PROJECT NO: _____ **W.O./J.O. NO:** _____ **PROJECT TITLE:** _____

ITEM NO.	NOMENCLATURE					FREON			MISC		WARRANTY		
	DESCRIPTION	SPEC SECTION	MODEL NO.	SERIAL NO.	SIZE	TYPE	LBS	OZS	DATE INSTALLED	LOCATION	START DATE	LENGTH OF WARRANTY	END DATE

TRANSFER AND ACCEPTANCE OF DoD REAL PROPERTY

PAGE
OF
PAGES

1. FROM (Organization Name)	2. DATE PREPARED (YYYYMMDD)	3. PROJECT/JOB NUMBER	4. SERIAL NUMBER	8. TRANSACTION DETAILS a. TYPE (X only one box) <input type="checkbox"/> ACQUISITION <input type="checkbox"/> TRANSFER BETWEEN SERVICES <input type="checkbox"/> CAPITAL IMPROVEMENT <input type="checkbox"/> INVENTORY ADJUSTMENT b. WHEN/EVENT (X one) <input type="checkbox"/> TOTAL ASSET PLACED-IN-SERVICE <input type="checkbox"/> PARTIAL ASSET PLACED-IN-SERVICE c. VERSION (X one) <input type="checkbox"/> DRAFT <input type="checkbox"/> INTERIM <input type="checkbox"/> FINAL
5. TO (Organization - Installation Code and Name)	6. RPSUID/SITENAME/ INSTCODE/INSTNAME	7. CONTRACT NUMBER(S)	7a. RPA PLACED-IN-SERVICE DATE (YYYYMMDD)	

9. ITEM NO.	10a. FACILITY NO.	10b. RPUID	11. CATCODE	12. CATCODE DESCRIPTION	13. CONS TYPE CODE	14. SUST CODE	PRIMARY		SECONDARY		19. COST	20. FUND SOURCE	21. FUND ORG	22. RPA INT TYPE CODE	23. ITEM REMARKS
							15. UMA	16. QUANTITY	17. UMO	18. QUANTITY					

24. STATEMENT OF COMPLETION. The facilities listed hereon are in accordance with maps, drawings, and specifications and change orders approved by the authorized representative of the using agency except for the deficiencies listed on the reverse side.		25. ACCEPTED BY (Typed Name and Signature)	
a. TITLE (Construction Agent/Installation Management Organization Accountable Official/RPAO)	c. DATE SIGNED (YYYYMMDD)	a. TITLE (Installation Management Organization Accountable Official/RPAO)	c. DATE SIGNED (YYYYMMDD)
b. TRANSFERRED BY (Typed Name and Signature)		b. NAME AND SIGNATURE	26. PROPERTY VOUCHER NUMBER

27. CONSTRUCTION DEFICIENCIES (Attach blank sheet for continuations)

28. PROJECT REMARKS (Attach blank sheet for continuations)

INSTRUCTIONS

GENERAL. This form has been designed and issued for acceptance of real property or transfer between the DoD Components.

For detailed instructions on how to fill out this form, please refer to Unified Facilities Criteria 1-300-08.

Existing instructions issued by the DoD Components relative to the preparation of DD Form 1354 are applicable to this revised form to the extent that the various items and columns on the superseded forms have been retained. The DoD Components may promulgate additional instructions, as appropriate.

For detailed information on data inputs and codes, please refer to the latest version of the Real Property Information Model (RPIM) Report and use the RPIM Pick Lists for Block responses:
<https://extranet.acq.osd.mil/ie/>

SPECIFIC DATA ITEMS.

1. **From.** Name of the DoD Component.
2. **Date Prepared.** Date of actual preparation. Enter all dates in YYYYMMDD format (Example: March 31, 2010 = 20100331).
3. **Project/Job Number.** Project number on a DD Form 1391 or Individual Job Order Number.
4. **Serial Number.** Sequential serial number assigned by the preparing organization (e.g., Item 17. 2010-0001).
5. **To.** Name and address of the receiving installation, activity, and Service of the Real Property Accountable Officer (RPAO).
6. **RPSUID/SITENAME/INSTCODE/INSTNAME.** Site Unique Identifier and name or installation code and name where the constructed facility is located.
7. **Contract Number(s).** Contract number(s) for this project.
- 7a. **RPA Placed-In-Service Date.** The calendar date the asset is accepted for use by DoD.
8. **Transaction Details.**
 - a. **Type of Transaction.** X only one box.
For Acquisition Type, refer to the Acquisition Method Code pick list in RPIM.
 - b. **When/Event.** When or event causing preparation of DD Form 1354. X only one box.
 - c. **Version.** Draft, interim, or final DD Form 1354. X only one box.
9. **Item Number.** Use a separate item number for each facility, no item number for additional usages.
- 10a. **Facility Number.** An installation specific asset identification number.
- 10b. **RPUID.** A unique non-intelligent code to permanently identify an asset.
11. **CATCODE.** The real property Category Code (CATCODE) that classifies the designed use of the asset (original or current) and corresponds to the largest quantity of the asset that is utilized for a single purpose (RPA Predominant Design Use CATCODE).
12. **CATCODE Description.** The CATCODE name corresponding with Item 11.

13. **Construction (CONS) Type Code.** The code represents the Construction Type Code and valid values can be found in the RPIM pick list by the same name. Type of construction will be PERM for Permanent or SEMI for Semi-permanent.

14. **Sustainability (SUST) Code.** : This code is also known as the Facility Sustainability Code and valid values can be found in the RPIM pick list by the same name. It indicates whether a facility meets the Guiding Principles of Federal Leadership in High Performance and Sustainable Buildings for buildings greater than 10,000 sq. ft. The list of valid values is: 1, 2, 3, 4.

15. **UMA.** Enter the primary unit of measure accountability for each design use category code for each item of real property.

16. **Quantity.** Enter the total quantity in the unit of measure accountability specified for each item of real property.

17. **UMO.** Enter the appropriate unit of measure operational for capacity/configuration as applicable for the design use category code.

18. **Quantity.** Enter the total quantity of capacity/configuration in the unit of measure operational specified for each item of real property.

19. **Cost.** Enter the total project cost for each item of real property. UFC 1-300-08 contains additional guidance.

20. **Fund Source.** Identify the fund source in this column for each real property asset or item. UFC 1-300-08 contains additional guidance.

21. **Funding Organization.** Identify the organization(s) responsible for funding the acquisition of this real property asset.

22. **RPA Interest Type Code.** This code represents the RPA Interest Type Code and valid values can be found in the RPIM pick list by the same name. The code is used to identify the type of legal interest that DoD holds in a real property asset.

23. **Item Remarks.** Remarks pertaining only to the item number identified in Item 9; show cost sharing.

24. **Statement of Completion.** Typed name, signature, title, and date of signature by the responsible transferring individual or agent. In the case of a real property acceptance action this is signed by the DoD Construction Agent. In the case of a real property transfer this is signed by the Installation Management Organization.

25. **Accepted By.** Typed name, signature, title, and date of signature by the Installation Management Organization RPAO or accepting official.

26. **Property Voucher Number.** Next sequential number assigned by the RPAO in voucher register.

27. **Construction Deficiencies.** List construction deficiencies in project during contractor turnover inspection.

28. **Project Remarks.** Project level remarks and continuation of blocks.

NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION

§ 77.7 Form and time of notice.

(a) If you are required to file notice under §77.9, you must submit to the FAA a completed FAA Form 7460-1, Notice of Proposed Construction or Alteration. FAA Form 7460-1 is available at FAA regional offices and on the Internet.

(b) You must submit this form at least 45 days before the start date of the proposed construction or alteration or the date an application for a construction permit is filed, whichever is earliest.

(c) If you propose construction or alteration that is also subject to the licensing requirements of the Federal Communications Commission (FCC), you must submit notice to the FAA on or before the date that the application is filed with the FCC.

(d) If you propose construction or alteration to an existing structure that exceeds 2,000 ft. in height above ground level (AGL), the FAA presumes it to be a hazard to air navigation that results in an inefficient use of airspace. You must include details explaining both why the proposal would not constitute a hazard to air navigation and why it would not cause an inefficient use of airspace.

(e) The 45-day advance notice requirement is waived if immediate construction or alteration is required because of an emergency involving essential public services, public health, or public safety. You may provide notice to the FAA by any available, expeditious means. You must file a completed FAA Form 7460-1 within 5 days of the initial notice to the FAA. Outside normal business hours, the nearest flight service station will accept emergency notices.

§ 77.9 Construction or alteration requiring notice.

If requested by the FAA, or if you propose any of the following types of construction or alteration, you must file notice with the FAA of:

(a) Any construction or alteration that is more than 200 ft. AGL at its site.

(b) Any construction or alteration that exceeds an imaginary surface extending outward and upward at any of the following slopes:

(1) 100 to 1 for a horizontal distance of 20,000 ft. from the nearest point of the nearest runway of each airport described in paragraph (d) of this section with its longest runway more than 3,200 ft. in actual length, excluding heliports.

(2) 50 to 1 for a horizontal distance of 10,000 ft. from the nearest point of the nearest runway of each airport described in paragraph (d) of this section with its longest runway no more than 3,200 ft. in actual length, excluding heliports.

(3) 25 to 1 for a horizontal distance of 5,000 ft. from the nearest point of the nearest landing and takeoff area of each heliport described in paragraph (d) of this section.

(c) Any highway, railroad, or other traverse way for mobile objects, of a height which, if adjusted upward 17 feet for an Interstate Highway that is part of the National System of Military and Interstate Highways where overcrossings are designed for a minimum of 17 feet vertical distance, 15 feet for any other public roadway, 10 feet or the height of the highest mobile object that would normally traverse the road, whichever is greater, for a private road, 23 feet for a railroad, and for a waterway or any other traverse way not previously mentioned, an amount equal to the height of the highest mobile object that would normally traverse it, would exceed a standard of paragraph (a) or (b) of this section.

(d) Any construction or alteration on any of the following airports and heliports:

(1) A public use airport listed in the Airport/Facility Directory, Alaska Supplement, or Pacific Chart Supplement of the U.S.

Government Flight Information Publications;

(2) A military airport under construction, or an airport under construction that will be available for public use;

(3) An airport operated by a Federal agency or the DOD.

(4) An airport or heliport with at least one FAA-approved instrument approach procedure.

(e) You do not need to file notice for construction or alteration of:

(1) Any object that will be shielded by existing structures of a permanent and substantial nature or by natural terrain or topographic features of equal or greater height, and will be located in the congested area of a city, town, or settlement where the shielded structure will not adversely affect safety in air navigation;

(2) Any air navigation facility, airport visual approach or landing aid, aircraft arresting device, or meteorological device meeting FAA-approved siting criteria or an appropriate military service siting criteria on military airports, the location and height of which are fixed by its functional purpose;

(3) Any construction or alteration for which notice is required by any other FAA regulation.

(4) Any antenna structure of 20 feet or less in height, except one that would increase the height of another antenna structure.

Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177
Fax: (817) 222-5920

Website: <https://oeaaa.faa.gov>

INSTRUCTIONS FOR COMPLETING FAA FORM 7460-1

PLEASE TYPE or PRINT

ITEM #1. Please include the name, address and phone number of a personal contact point as well as the company name.

ITEM #2. Please include the name, address and phone number of a personal contact point as well as the company name.

ITEM #3. New Construction would be a structure that has not yet been built.

Alteration is a change to an existing structure such as the addition of a side mounted antenna, a change to the marking and lighting, a change to power and/or frequency, or a change to the height. The nature of the alteration shall be included in ITEM #21 "Complete Description of Proposal".

Existing would be a correction to the latitude and/or longitude, a correction to the height, or if filing on an existing structure which has never been studied by the FAA. The reason for the notice shall be included in ITEM #21 "Complete Description of Proposal".

ITEM #4. If Permanent, so indicate. If Temporary, such as a crane or drilling derrick, enters the estimated length of time the temporary structure will be up.

ITEM #5. Enter the date that construction is expected to start and the date that construction should be completed.

ITEM #6. Please indicate the type of structure. DO NOT LEAVE BLANK.

ITEM #7. In the event that obstruction marking and lighting is required, please indicate type desired. If no preference, check "other" and indicate "no preference" DO NOT LEAVE BLANK. NOTE: High Intensity lighting shall be used only for structures over 500' AGL. In the absence of high intensity lighting for structures over 500' AGL, marking is also required.

ITEM #8. If this is an existing tower that has been registered with the FCC, enter the FCC Antenna Structure Registration number here.

ITEM #9 and #10. Latitude and longitude must be geographic coordinates, accurate to within the nearest second or to the nearest hundredth of a second if known. Latitude and longitude derived solely from a hand-held G P S instrument is NOT acceptable. A hand-held GPS is only accurate to within 100 meters (328 feet) 95 percent of the time. This data, when plotted, should match the site depiction submitted under ITEM #20.

ITEM #11. NAD 83 is preferred; however, latitude and longitude may be submitted in NAD 27. Also, in some geographic areas where NAD 27 and NAD 83 are not available other datum may be used. It is important to know which datum is used. DO NOT LEAVE BLANK.

ITEM #12. Enter the name of the nearest city and state to the site. If the structure is or will be in a city, enter the name of that city and state.

ITEM #13. Enter the full name of the nearest public-use (not private-use) airport or heliport or military airport or heliport to the site.

ITEM #14. Enter the distance from the airport or heliport listed in #13 to the structure.

ITEM #15. Enter the direction from the airport or heliport listed in #13 to the structure.

ITEM #16. Enter the site elevation above mean sea level and expressed in whole feet rounded to the nearest foot (e.g. 17'3" rounds to 17', 17'6" rounds to 18'). This data should match the ground contour elevations for site depiction submitted under ITEM #20.

ITEM #17. Enter the total structure height above ground level in whole feet rounded to the next highest foot (e.g. 17'3" rounds to 18'). The total structure height shall include anything mounted on top of the structure, such as antennas, obstruction lights, lightning rods, etc.

ITEM #18. Enter the overall height above mean sea level and expressed in whole feet. This will be the total of ITEM #16 + ITEM #17.

ITEM #19. If an FAA aeronautical study was previously conducted, enter the previous study number.

ITEM #20. Enter the relationship of the structure to roads, airports, prominent terrain, existing structures, etc. Attach an 8-1/2" x 11" non-reduced copy of the appropriate 7.5 minute U.S. Geological Survey (USGS) Quadrangle Map MARKED WITH A PRECISE INDICATION OF THE SITE LOCATION. To obtain maps, contact USGS at 1-888-275-8747 or via internet at "<http://store.usgs.gov>". If available, attach a copy of a documented site survey with the surveyor's certification stating the amount of vertical and horizontal accuracy in feet.

ITEM #21.

- For transmitting stations, include maximum effective radiated power (ERP) and all frequencies.
- For antennas, include the type of antenna and center of radiation (Attach the antenna pattern, if available).
- For microwave, include azimuth relative to true north.
- For overhead wires or transmission lines, include size and configuration of wires and their supporting structures (Attach depiction).
- For each pole/support, include coordinates, site elevation, and structure height above ground level or water.
- For buildings, include site orientation, coordinates of each corner, dimensions, and construction materials.
- For alterations, explain the alteration thoroughly.
- For existing structures, thoroughly explain the reason for notifying the FAA (e.g. corrections, no record or previous study, etc.).

Filing this information with the FAA does not relieve the sponsor of this construction or alteration from complying with any other federal, state or local rules or regulations. If you are not sure what other rules or regulations apply to your proposal, contact local/state aviation's and zoning authorities.

Paperwork Reduction Work Act Statement: A federal agency may not conduct or sponsor, and a person is not required to respond to, nor shall a person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act unless that collection displays a currently valid OMB Control Number. The OMB control number for this information collection is 2120-0001. Public reporting for this collection of information is estimated to be approximately 19 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, completing and reviewing the collection of information. All responses to this collection of information are mandatory for anyone proposing construction or alteration that meets the criteria contained in 14 CFR 77. This information is collected to evaluate the effect of proposed construction or alteration on air navigation and is not confidential. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to: Information Collection Clearance Officer, Federal Aviation Administration, 10101 Hillwood Parkway, Fort Worth, TX 76177-1524.

Paperwork reduction Act statement: A Federal agency may not conduct or sponsor, and a person is not required to respond to, nor shall a person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act unless that collection displays a currently valid OMB Control Number. The OMB control number for this collection is 2120-0001. Public reporting for this collection of information is estimated to be approximately 15 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, completing and reviewing the collection of information. All responses to this collection of information are mandatory for anyone proposing construction or alteration that meets the criteria contained in 14 CFR 77. This information is collected to process obstruction data that is critical to flight safety and is not confidential. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to: Information Clearance Officer, Federal Aviation Administration, 10101 Hillwood Parkway, Fort Worth, TX 76177-1524.

Privacy Act Statement (5 U.S.C. § 552a, as amended): AUTHORITY: The FAA is responsible for issuing a determination based on extensive analysis completed in accordance with 49 United States Code (USC) Section 44718. Title 14 of the Code of Federal Regulations (14 CFR), part 77 authorizes FAA to collect this information. PURPOSE(S): FAA will use the information provided to administer the Aeronautical Study Process. ROUTINE USE(S): In accordance with DOT's system of records notice, DOT/ALL 16 Mailing Management System & DOT/FAA 826 Petitions for Exemption, Other than Medical Exemption-Public Dockets, the information provided may be disclosed to officials within the Federal government and the public in general.

Form Approved OMB No. 2120-0001
Expiration Date: 05/31/2026

SUPPLEMENTAL NOTICE

Submission Instructions: For Advance Notice of Actual Construction or Alteration. Complete items 1, 2, 3A (1), 3A(2), and 6. If applicable, also complete items 4 and 5. Detach Part 1. Fold and tape at bottom. Mail to the FAA Regional Office for your area. Part 1A is provided for your file.	Aeronautical Study No.
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U.S. Department of Transportation Federal Aviation Administration	Notice of Actual Construction or Alteration <i>(Please Type or Print on this Form)</i>
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1. Construction

A. Type and Description of Construction <input type="checkbox"/> New <input type="checkbox"/> Alteration	B. Owner of Structure
---	------------------------------

2. Construction Location -- Height

A. Coordinates (To hundredths of seconds, if known) <table style="width:100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Latitude</td> <td style="text-align: center;">Longitude</td> </tr> <tr> <td style="text-align: center;">° ' "</td> <td style="text-align: center;">° ' "</td> </tr> </table>	Latitude	Longitude	° ' "	° ' "	B. Location (City, State, include Street Address if any)								
Latitude	Longitude												
° ' "	° ' "												
C. Construction Heights <table style="width:100%; border-collapse: collapse;"> <tr> <td style="width:33%;">Site Elevation</td> <td style="width:33%;">Ft. AMSL</td> <td style="width:33%;">Total Height</td> </tr> <tr> <td>Structure Height</td> <td>Ft. AGL</td> <td>(Structure & Site)</td> </tr> <tr> <td></td> <td></td> <td>Above Mean Sea Level</td> </tr> <tr> <td></td> <td></td> <td>Ft. AMSL</td> </tr> </table>	Site Elevation	Ft. AMSL	Total Height	Structure Height	Ft. AGL	(Structure & Site)			Above Mean Sea Level			Ft. AMSL	F. Name of Nearest Public-Use or Military Airport <i>(include Distance and Direction from the Airport)</i>
Site Elevation	Ft. AMSL	Total Height											
Structure Height	Ft. AGL	(Structure & Site)											
		Above Mean Sea Level											
		Ft. AMSL											
D. Site Elevation Determined By <input type="checkbox"/> Actual Survey <input type="checkbox"/> USGS 7.5' Quad Chart <input type="checkbox"/> Other (Specify)	E. Reference datum of coordinates <input type="checkbox"/> NAD 27 <input type="checkbox"/> NAD 83 <input type="checkbox"/> Other (Specify)												

3. Construction Notifications

A. Notification <div style="text-align: center; color: red; font-weight: bold; font-size: small;"> (Notice is Critical to Flight Safety -- FAR Part 77 Required) ★ </div>	Date	B. Construction/Project Date
(1) Construction will start (Submit at least 48 hrs. in advance)		(1) Project Abandoned
(2) Estimated Completion		(2) Construction Dismantled
(3) Structure Reached Greatest Height (Submit within 5 days)		

4. Marking and Lighting

A. Marked <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Temporary	B. Lighted <table style="width:100%; border-collapse: collapse;"> <tr> <td><input type="checkbox"/> Medium Intensity White</td> <td><input type="checkbox"/> High Intensity White</td> <td><input type="checkbox"/> Red</td> </tr> <tr> <td><input type="checkbox"/> Dual (Medium Intensity White & Red)</td> <td><input type="checkbox"/> Dual (High Intensity White & Red)</td> <td><input type="checkbox"/> None</td> </tr> </table>	<input type="checkbox"/> Medium Intensity White	<input type="checkbox"/> High Intensity White	<input type="checkbox"/> Red	<input type="checkbox"/> Dual (Medium Intensity White & Red)	<input type="checkbox"/> Dual (High Intensity White & Red)	<input type="checkbox"/> None
<input type="checkbox"/> Medium Intensity White	<input type="checkbox"/> High Intensity White	<input type="checkbox"/> Red					
<input type="checkbox"/> Dual (Medium Intensity White & Red)	<input type="checkbox"/> Dual (High Intensity White & Red)	<input type="checkbox"/> None					

5. Antenna Requiring FCC License

A. Call Sign	B. Frequency	C. Date Applied for FCC Construction Permit	D. Date Construction Permit Issued
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6. Preparer's Certification

Submitted by: (if submitted by a proponent's representative, please also complete item B.)	A. Proponent's Representative Name: Address: Tel. No.: (Include Area Code)	B. Construction Proponent Name: Address: Tel. No.: (Include Area Code)	
	I hereby certify that the information provided is true, complete, and correct to the best of my knowledge.		
	Signature	Title	Date
	Notice is required by 14 Code of Federal Regulations, part 77 pursuant to 49 U.S.C., Section 44718. Persons who knowingly and willingly violate the notice requirements of part 77 are subject to a civil penalty of \$1,000 per day until the notice is received, pursuant to 49 U. & C., Section 46301(a).		

