



# Type B-3 Specifications (100%)

Mission Training Center  
Texas Air National Guard 149<sup>th</sup> FW

Volume 2 of 2



NGB Contract: W9133L16D0005  
Task Order: W912L1-19-F-0014  
TX ANG PN: KELL189014  
15 AUGUST 2024



FSB  
FEDERAL DESIGN  
GROUP JV

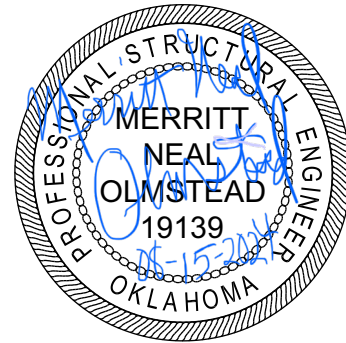




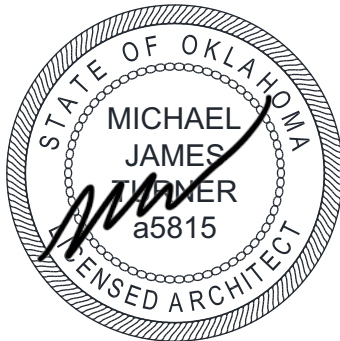
F-16 Mission Training Center  
PN: KELL169014  
Joint Base San Antonio, Kelly Annex, TX



*Lindsay Hausman*



Structural



Architectural

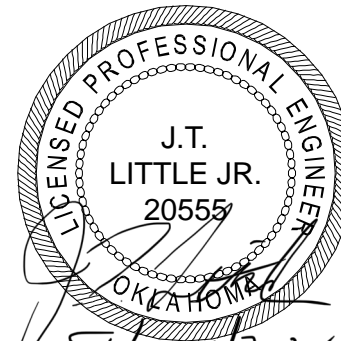


Fire Protection



08/15/2024

Mechanical



8/15/2024

Electrical





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WET PIPE SPRINKLER SYSTEM, FIRE PROTECTION  
05/09

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 SANITARY ENGINEERING (ASSE)

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 for Water  
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

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME A13.1 (2023) Scheme for the Identification of Piping Systems  
ASME B16.1 (2020) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250  
ASME B16.11 (2016) Forged Fittings, Socket-Welding and Threaded  
ASME B16.21 (2021) Nonmetallic Flat Gaskets for Pipe Flanges  
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 B16.9 (2012) Standard for Factory-Made Wrought



Steel Buttwelding Fittings

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 A135/A135M	(2021) Standard Specification for Electric-Resistance-Welded Steel Pipe
ASTM A183	(2014) 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 A449	(2023) 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 A53/A53M	(2022) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
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 A795/A795M	(2013) Standard Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use
ASTM F436	(2011) Hardened Steel Washers
U.S. DEPARTMENT OF DEFENSE (DOD)	
MIL-STD-101	(2014; Rev C) Color Code for Pipelines and for Compressed Gas Cylinders
FM GLOBAL (FM)	
FM APP GUIDE	(updated on-line) Approval Guide <a href="http://www.approvalguide.com/">http://www.approvalguide.com/</a>
MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)	
MSS SP-71	(2018) Gray Iron Swing Check Valves,

Flanged and Threaded Ends

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 101	(2021; TIA 21-1) Life Safety Code
NFPA 13	(2022) Standard for the Installation of Sprinkler Systems
NFPA 1963	(2019) Standard for Fire Hose Connections
NFPA 24	(2022) Standard for the Installation of Private Fire Service Mains and Their Appurtenances

NATIONAL INSTITUTE FOR CERTIFICATION IN ENGINEERING TECHNOLOGIES (NICET)

NICET 1014-7	(2010) Program Detail Manual for Certification in the Field of Fire Protection Engineering Technology (Field Code 003) Subfield of Automatic Sprinkler System Layout
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U.S. DEPARTMENT OF DEFENSE (DOD)

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

UL 668	(2004; Reprint Jul 2016) UL Standard for Safety Hose Valves for Fire-Protection Service
UL Bld Mat Dir	(updated continuously online) Building Materials Directory
UL Fire Prot Dir	(2012) Fire Protection Equipment Directory

1.2 SYSTEM DESCRIPTION

Furnish piping, offsets, fittings, and any other accessories as required to provide a complete installation and to eliminate interference with other construction. Install sprinkler system over and under ducts, piping and platforms when such equipment can negatively effect or disrupt the sprinkler discharge pattern and coverage. Provide wet pipe sprinkler system in all areas of the building. The system shall be designed and installed in accordance with UFC 3-600-01 and NFPA 13. Pipe sizes which are not indicated on drawings shall be determined by hydraulic calculation. Design any portions of the sprinkler system that are not indicated on the drawings including locating sprinklers, piping and equipment, and size piping and equipment when this information is not indicated on the drawings or is not specified herein. The design of the sprinkler system shall be based on hydraulic calculations, UFC 3-600-01, and the other provisions specified herein.

### 1.2.1 Hydraulic Design

Hydraulically design the system to discharge a minimum density over the hydraulically most demanding floor area, determined as required by UFC 3-600-01 and the drawings. Light Hazard areas shall be 0.1 gpm/sf over 1,500 sf, K=5.6 sprinklers. Ordinary Hazard shall be 0.2 gpm/sf over 2,500 sf with K=8 sprinklers. Do not use area reductions below those in UFC 3-600-01 Table 9-3. For areas with ceiling heights over 30 feet, utilize K=11.2 sprinklers. The minimum pipe size for branch lines in gridded systems shall be 1-1/4 inch. Hydraulic calculations shall be in accordance with the Area/Density Method of NFPA 13.

#### 1.2.1.1 Hose Demand

Add an allowance for exterior hose streams of 250 gpm to the sprinkler system demand at the point of connection to the existing system.

#### 1.2.1.2 Basis for Calculations

The design of the system shall be based upon contractor performed flow test under the direction of the Qualified Fire Protection Engineer (QFPE). Historic water supply from May 9, 2019 has a static pressure of 70 psi, and a flow of 1,150 gpm at a residual pressure of 55 psi. Water supply shall be presumed available at the flange of the pressure hydrant. Hydraulic calculations shall be based upon the Hazen-Williams formula with a "C" value of 120 for steel piping, 150 for PVC and stainless steel piping, and 140 for new cement-lined ductile-iron piping, and 100 for existing underground piping. Calculations shall include a minimum pressure drop of 8 psi across the backflow preventer and a minimum 10 percent margin of safety.

#### 1.2.1.3 Hydraulic Calculations

Submit hydraulic calculations, including a drawing showing hydraulic reference points and pipe segments and as outlined in NFPA 13, except that calculations shall be performed by computer using software intended specifically for fire protection system design using the design data shown on the drawings and shall utilize the Area/Density Method of NFPA 13. Software that uses k-factors for typical branch lines is not acceptable. Calculations shall substantiate that the design area used in the calculations is the most demanding hydraulically.

Water supply curves and system requirements shall be plotted on semi-logarithmic graph paper so as to present a summary of the complete hydraulic calculation. Provide a summary sheet listing sprinklers in the design area and their respective hydraulic reference points, elevations, actual discharge pressures and actual flows. Elevations of hydraulic reference points (nodes) shall be indicated. Documentation shall 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. For gridded systems, calculations shall show peaking of demand area friction loss to verify that the hydraulically most demanding area is being used. Also for gridded systems, a flow diagram indicating the quantity and direction of flows shall be included. A drawing showing hydraulic reference points (nodes) and pipe designations used in the calculations shall be included and shall be independent of shop drawings.

### 1.2.2 Sprinkler Coverage

Sprinklers shall be uniformly spaced on branch lines. Sprinklers shall provide coverage throughout 100 percent of the building. This includes, but is not limited to, telephone rooms, electrical equipment rooms, boiler rooms, switchgear rooms, transformer rooms, and other electrical and mechanical spaces. Coverage per sprinkler shall be in accordance with NFPA 13, but shall not exceed 130 square feet for ordinary hazard occupancies, and 225 square feet for light hazard occupancies. Exceptions are as follows:

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

### 1.3 SUBMITTALS

Government approval is required for all submittals. 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 Drawings; G  
As-Built Drawings; G

#### SD-03 Product Data

Fire Protection Related Submittals; G  
Materials and Equipment; G  
Spare Parts  
Onsite Training

#### SD-05 Design Data

Hydraulic Calculations; G

#### SD-06 Test Reports

Preliminary Test Procedures; G  
Preliminary Test Report; G  
Final Acceptance Test Procedures; G  
Final Acceptance Test Report; G

#### SD-07 Certificates

Certification By Qfpe

#### SD-08 Manufacturer's Instructions

Posted O&M Instructions ; G

#### SD-10 Operation and Maintenance Data

Operating and Maintenance Manuals; G

#### 1.4 QUALITY ASSURANCE

Compliance with referenced NFPA standards is mandatory. In the event of a conflict between specific provisions of this specification and applicable NFPA standards, this specification governs. Interpret reference to "authority having jurisdiction" to mean the Contracting Officer.

##### 1.4.1 Qualified Fire Protection Engineer (QFPE)

Perform work specified in this section under the supervision of and certified by the QFPE who is an individual registered professional engineer who has passed the fire protection engineering written examination administered by the National Council of Examiners for Engineering and Surveys (NCEES) in fire protection, and that has a minimum of 5 years relevant experience dedicated to fire protection engineering that can be verified with documentation. Submit the name and documentation of certification of the proposed QFPE, no later than 14 days after the Notice to Proceed and prior to the submittal of the sprinkler system drawings and hydraulic calculations.

The Qualified Fire Protection Engineer shall prepare and submit a list of the fire protection related submittals, no later than 7 days after the approval of the Fire Protection Specialist, from the Contract Submittal Register that relate to the successful installation of the sprinkler systems(s).

##### 1.4.2 Sprinkler System Designer

The Sprinkler System designer shall be certified as a Level III Technician by the 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.

##### 1.4.3 Sprinkler System Installer

Work specified in this section shall be performed by the Sprinkler System Installer who is regularly engaged in the installation of the type and complexity of system specified in the contract documents, and who has 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. Submit the name and documentation of certification of the proposed Sprinkler System Installer, concurrent with submittal of the Fire Protection Specialist Qualifications.

##### 1.4.4 Shop Drawings

Shop Drawings shall conform to the requirements established for working plans as prescribed in NFPA 13. Submit the Sprinkler System shop drawings, no later than 30 days prior to the start of sprinkler system installation. Drawings shall include plan and elevation views demonstrating that the equipment will fit the allotted spaces with clearance for installation and maintenance. Each set of drawings shall include the following:

- a. Descriptive index of drawings in the submittal with drawings listed in sequence by drawing number. A legend identifying device symbols, nomenclature, and conventions used.



- b. Floor plans drawn to a scale not less than 1/8" = 1'-0" which clearly show locations of sprinklers, risers, pipe hangers, inspector's test connections, drains, and other applicable details necessary to clearly describe the proposed arrangement. Each type of fitting used and the locations of reducing couplings (where approved) and welded joints shall be indicated.
- c. 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 shall show the dimension from the sprinkler and sprinkler deflector to the ceiling in finished areas.
- d. Longitudinal and transverse building sections showing typical branch line and cross-main pipe routing as well as elevation of each typical sprinkler above finished floor.
- e. Details of each type of riser assembly; pipe hanger; restraint of underground water main at point-of-entry into the building, and electrical devices and interconnecting wiring.
- f. Shop drawings and hydraulic calculations shall be prepared by a NICET III or IV technician and reviewed and stamped by the Fire Protection Specialist before submitting for review.

#### 1.5 DELIVERY, STORAGE, AND HANDLING

All equipment delivered and placed in storage shall be housed in a manner to preclude any damage from the weather, humidity and temperature variations, dirt and dust, or other contaminants. Additionally, all pipes shall either be capped or plugged until installed.

#### 1.6 SPARE PARTS (EXTRA MATERIALS)

Submit spare parts data for each different item of material and equipment 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.

### PART 2 PRODUCTS

#### 2.1 STANDARD PRODUCTS

Provide materials and equipment which are standard products of a manufacturer 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.

#### 2.2 NAMEPLATES

All equipment shall have a nameplate that identifies the manufacturer's name, address, type or style, model or serial number, and catalog number.

#### 2.3 REQUIREMENTS FOR FIRE PROTECTION SERVICE

Provide Materials and Equipment that have been tested by Underwriters

Laboratories, Inc. and are 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. Submit manufacturer's catalog data included with the Sprinkler System Drawings for all items specified herein. The data shall be highlighted to show model, size, options, etc., that are intended for consideration. Data shall be adequate to demonstrate compliance with all contract requirements. In addition, provide a complete equipment list that includes equipment description, model number and quantity.

## 2.4 UNDERGROUND PIPING COMPONENTS

### 2.4.1 Pipe

Piping from a point 6 inches above the floor to 5 feet outside the building wall shall be a welded, continuous stainless steel lead-in terminating with a flange at 12" above the floor. Piping more than 5 feet outside the building walls shall comply with SAWS Requirements and Civil Drawings.

### 2.4.2 Fittings and Gaskets

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

### 2.4.3 Gate Valve and Indicator Posts

Gate valves for underground installation shall be of the inside screw type with counter-clockwise rotation to open. Where indicating type valves are shown or required, indicating valves shall be gate valves with an approved indicator post of a length to permit the top of the post to be located 3 feet above finished grade. Gate valves and indicator posts shall be listed in UL Fire Prot Dir or FM APP GUIDE and shall be provided with a tamper switch monitored by the fire alarm system..

## 2.5 ABOVEGROUND PIPING COMPONENTS

Aboveground piping shall be steel.

### 2.5.1 Steel Piping Components

#### 2.5.1.1 Steel Pipe

Except as modified herein, pipe shall be black steel as permitted by NFPA 13 and shall conform to applicable provisions of ASTM A795/A795M, ASTM A53/A53M, or ASTM A135/A135M. Piping shall be Schedule 40. Pipe shall be marked with the name of the manufacturer, kind of pipe, and ASTM designation.

#### 2.5.1.2 Fittings for Non-Grooved Steel Pipe

Fittings shall be cast iron conforming to ASME B16.4, steel conforming to ASME B16.9 or ASME B16.11, or malleable iron conforming to ASME B16.3. Steel press fittings shall not be used. Fittings into which sprinklers, drop nipples or riser nipples (sprigs) are screwed shall be threaded type. Plain-end fittings with mechanical couplings, press fittings,

saddle tees, fittings that use steel gripping devices to bite into the pipe and segmented welded fittings shall not be used.

#### 2.5.1.3 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; segmented welded fittings shall not be used. 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.

#### 2.5.1.4 Flanges

Flanges shall conform to NFPA 13 and ASME B16.1. Gaskets shall be non-asbestos compressed material in accordance with ASME B16.21, 1/16 inch thick, and full face or self-centering flat ring type.

#### 2.5.1.5 Bolts, Nut, and Washers

Bolts shall conform to ASTM A449, Type 1 and shall extend no less than three full threads beyond the nut with bolts tightened to the required torque. Nuts shall be hexagon type conforming to ASME B18.2.2, ASTM A193/A193M, Grade 5 or ASTM A563, Grade C3. Washers shall meet the requirements of ASTM F436. Flat circular washers shall be provided under all bolt heads and nuts.

#### 2.5.1.6 Flexible Sprinkler Hose Fittings

Flexible Sprinkler fittings shall not be used.

#### 2.5.2 Pipe Hangers

Hangers shall be listed in UL Fire Prot Dir or FM APP GUIDE and of the type suitable for the application, construction, and pipe type and sized to be supported.

#### 2.5.3 Valves

##### 2.5.3.1 Control Valve and Gate Valve

Manually operated sprinkler control valve and gate valve shall be outside stem and yoke (OS&Y) type and shall be listed in UL Bld Mat Dir or FM APP GUIDE.

##### 2.5.3.2 Check Valve

Check valve 2 inches and larger shall be listed in UL Bld Mat Dir or FM APP GUIDE. Check valves 4 inches and larger shall be of the swing type with flanged cast iron body and flanged inspection plate, shall have a clear waterway and shall meet the requirements of MSS SP-71, for Type 3 or 4.

##### 2.5.3.3 Hose Valve

Valve shall comply with UL 668 and shall have a minimum rating of 300 psi. Valve shall be non-rising stem, all bronze, 90 degree angle type, with

2-1/2 inch American National Standard Fire Hose Screw Thread (NH) male outlet in accordance with NFPA 1963. Hose valve shall be provided with 2-1/2 to 1-1/2 inch reducer. Hose valves shall be equipped with lugged cap with drip drain, cap gasket and chain. Valve finish shall be polished chrome plated.

## 2.6 RISER CHECK VALVE ASSEMBLY

Assembly shall include a riser check valve, standard trim piping, pressure gauges, testing valves, main drain, and other components as required for a fully operational system.

## 2.7 WATERFLOW ALARM

Electrically operated, exterior-mounted, waterflow alarm shall be as provided in Section 28 31 76 INTERIOR FIRE ALARM AND MASS NOTIFICATION SYSTEM.

## 2.8 ALARM INITIATING AND SUPERVISORY DEVICES

### 2.8.1 Sprinkler Waterflow Indicator Switch, Vane Type

Switch shall be vane type with a pipe saddle and cast aluminum housing. The electro-mechanical device shall include a flexible, low-density polyethylene paddle conforming to the inside diameter of the fire protection pipe. The device shall sense water movements and be capable of detecting a sustained flow of 10 gpm or greater. The device shall contain a retard device adjustable from 0 to 90 seconds to reduce the possibility of false alarms caused by transient flow surges. The switch shall be tamper resistant and contain two SPDT (Form C) contacts arranged to transfer upon removal of the housing cover, and shall be equipped with a silicone rubber gasket to assure positive water seal and a dustproof cover and gasket to seal the mechanism from dirt and moisture.

### 2.8.2 Valve Supervisory (Tamper) Switch

Switch shall be suitable for mounting to the type of control valve to be supervised open. The switch shall be tamper resistant and contain one set of 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.

## 2.9 DOUBLE-CHECK VALVE BACKFLOW PREVENTION ASSEMBLY

Double-check backflow prevention assembly shall comply with ASSE 1015. The assembly shall have a bronze, cast-iron or stainless steel body with flanged ends. The assembly shall include pressure gauge test ports and OS&Y shutoff valves on the inlet and outlet, 2-positive-seating check valves for continuous pressure application, and four test cocks. Assemblies shall be rated for working pressure of 175 psi. The maximum pressure loss shall be 6 psi at a flow rate equal to the sprinkler water demand, at the location of the assembly. A test port for a pressure gauge shall be provided both upstream and downstream of the double check backflow prevention assembly valves.

## 2.10 BACKFLOW PREVENTER TEST CONNECTION

Connection shall be flush type with cast brass body, matching wall escutcheon and signage lettered "TEST" with a chromium plated finish. The connection shall have three outlets, (max 250 gpm/outlet), hose valves,

caps with drip drains and chains. Provide 2-1/2 inch diameter American National Fire Hose Connection Screw Threads (NH) per NFPA 1963. Drain valve and discharge piping shall slope to exterior wall and discharge onto splash block 12" to 18" above grade.

#### 2.11 FIRE DEPARTMENT CONNECTION

Fire department connection shall be flush type with cast brass body, matching wall escutcheon lettered "Auto Spkr" with a polished chromium plated finish. the connection shall have a three inlets (maximum 250 gpm/inlet) with individual self-closing clappers, caps with drip drains and chains. Female inlets shall have 2-1/2 inch diameter American National Fire Hose Connection Screw Threads (NH) per NFPA 1963.

#### 2.12 SPRINKLERS

Sprinklers with internal O-rings shall not be used. Sprinklers shall be used in accordance with their listed coverage limitations. Temperature classification shall be ordinary. Sprinklers in high heat areas including attic spaces or in close proximity to unit heaters shall have temperature classification in accordance with NFPA 13. Extended coverage sprinklers shall not be used. Sprinklers for server rooms shall be standard response, intermediate temperature classification, and shall be provided with a control valve and tamper switch, monitored by the fire alarm system.

##### 2.12.1 Concealed Sprinkler

Concealed sprinkler shall be chrome-plated or white polyester quick-response type and shall have a nominal 1/2 inch or 17/32 inch orifice.

##### 2.12.2 Recessed Sprinkler

Recessed sprinkler shall be chrome-plated or white polyester quick-response type and shall have a nominal 1/2 inch or 17/32 inch orifice.

##### 2.12.3 Pendent Sprinkler

Pendent sprinkler shall be of the fusible strut or glass bulb type, recessed quick-response type with nominal 1/2 inch or 17/32 inch orifice. Pendent sprinklers shall have a polished chrome or white polyester finish.

##### 2.12.4 Upright Sprinkler

Upright sprinkler shall be brass, chrome-plated, stainless steel or white polyester quick-response type and shall have a nominal 1/2 inch or 17/32 inch orifice.

##### 2.12.5 Sidewall Sprinkler

Sidewall sprinkler shall have a nominal 1/2 inch orifice. Sidewall sprinkler shall have a polished chrome or white polyester finish. Sidewall sprinkler shall be the quick-response type.



## 2.13 ACCESSORIES

### 2.13.1 Sprinkler Cabinet

Spare sprinklers shall be provided in accordance with NFPA 13 and shall be packed in suitable metal or plastic cabinets. Spare sprinklers shall be representative of, and in proportion to, the number of each type and temperature rating of the sprinklers installed. At least one wrench of each type required shall be provided.

### 2.13.2 Pendent Sprinkler Escutcheon

Escutcheon shall be one-piece metallic type with a depth of less than 3/4 inch and suitable for installation on pendent sprinklers. The escutcheon shall have a factory finish that matches the pendent sprinkler heads.

### 2.13.3 Pipe Escutcheon

Escutcheon shall be polished chromium-plated zinc alloy, or polished chromium-plated copper alloy. Escutcheons shall be either one-piece or split-pattern, held in place by internal spring tension or set screw.

### 2.13.4 Sprinkler Guard

Guard shall be a steel wire cage designed to encase the sprinkler and protect it from mechanical damage. Guards shall be provided on sprinklers located below 7' above the floor and as indicated.

### 2.13.5 Identification Sign

Valve identification sign shall be minimum 6 inches wide by 2 inches high with enamel baked finish on minimum 18 gauge steel or 0.024 inch aluminum with red letters on a white background or white letters on red background. Wording of sign shall 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. All control valves shall be identified with permanent signs stating "NORMALLY OPEN" or "NORMALLY CLOSED". Provide permanent engraved hydraulic sign.

## Posted O&M Instructions

Provide posted O&M instructions, weatherproof, framed in heavy gauge extruded metal frames, mounted under glass. Instructions shall be permanently mounted, complete with professionally prepared graphics, printed in color on full sized sheets. Prepare instructions for all systems and include all components.

## PART 3 EXECUTION

### 3.1 FIELD MEASUREMENTS

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 REQUIREMENTS

The installation shall be in accordance with the applicable provisions of

NFPA 13, NFPA 24, UFC 3-600-01 and publications referenced therein. Brace equipment over 31 pounds per force protection requirements.

### 3.3 CERTIFICATION BY QFPE

Prior to ceiling installation and concurrent with the Final Acceptance Test Report, certification by the QFPE that the sprinkler system is installed in accordance with the contract requirements, including signed approval of the Preliminary and Final Acceptance Test Reports. The QFPE shall:

- 1) Inspect the sprinkler system periodically during the installation to assure that the sprinkler system is being provided and installed in accordance with the contract requirements.
- 2) Witness the preliminary and final tests, and sign the test results.
- 3) After completion of the system inspections and a successful final test, certify in writing that the system has been installed in accordance with the contract requirements. 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.

### 3.4 ABOVEGROUND PIPING INSTALLATION

#### 3.4.1 Piping in Exposed Areas

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

#### 3.4.2 Piping in Finished Areas

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

#### 3.4.3 Pendent Sprinklers

Concealed or recessed sprinklers shall be provided in all areas with suspended ceilings. Drop nipples to pendent sprinklers shall consist of minimum 1 inch pipe with a reducing coupling into which the sprinkler shall be threaded. Hangers shall be provided on arm-overs to drop nipples supplying pendent sprinklers when the arm-over exceeds 12 inches for steel pipe. Sprinklers shall not be installed below suspended or dropped ceilings. Recessed pendent sprinklers shall be installed such that the distance from the sprinkler deflector to the underside of the ceiling shall not exceed the manufacturer's listed range and shall be of uniform depth throughout the finished area. Pendent sprinklers in suspended ceilings shall be a minimum of 6 inches from ceiling grid.

#### 3.4.4 Upright Sprinklers

Riser nipples or "sprigs" to upright sprinklers shall contain no fittings between the branch line tee and the reducing coupling at the sprinkler. Riser nipples exceeding 30 inches in length shall be individually supported.

#### 3.4.5 Pipe Joints

Pipe joints shall conform to NFPA 13, and to the requirements herein. Not more than four threads shall 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 shall be provided where indicated or required by NFPA 13. Grooved pipe and fittings shall 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 shall be products of the same 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 and recorded 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 provided and shown on the drawings for servicing or adjusting the joint.

#### 3.4.6 Reducers

Reductions in pipe sizes shall be made with one-piece tapered reducing fittings. The use of grooved-end or rubber-gasketed reducing couplings or bushings will not be permitted.

#### 3.4.7 Pipe Penetrations

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 shall be core-drilled and provided with pipe sleeves. Each sleeve shall be Schedule 40 galvanized steel, ductile iron or cast iron pipe and shall extend through its respective wall or floor and be cut flush with each wall surface. Sleeves shall provide required clearance between the pipe and the sleeve per NFPA 13. The space between the sleeve and the pipe shall be firmly packed with mineral wool insulation. Where pipes penetrate fire barriers, pipes shall be firestopped in accordance with Section 07 84 00 FIRESTOPPING by the approved firestop installer. In penetrations that are not fire-rated or not a floor penetration, the space between the sleeve and the pipe shall 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. Penetrations through the secure perimeter shall be grounded within 6" of the inside of the wall. Penetrations thru STC rated walls shall be grounded on both sides of the wall, within 6" of the wall. Grounding shall be with #4 copper wire to earth.

#### 3.4.8 Escutcheons

Escutcheons shall be provided for pipe penetration of ceilings and walls. Escutcheons shall be securely fastened to the pipe at surfaces through which piping passes.

#### 3.4.9 Automatic Air Vents

Provide automatic air vents at high points in the system to vent at least 95% of the volumetric capacity of the system. Reduce the quantity of air

vents by connecting branch lines or providing cross main at the peak.

#### 3.4.10 Inspector's Test Connection

Unless otherwise indicated, test connection shall consist of 1 inch pipe connected at the riser as a combination test and drain valve or a test valve located approximately 7 feet above the floor; shall be 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." The discharge orifice shall be located outside the building wall directed onto a concrete splash block and so as not to cross pedestrian traffic or cause damage to adjacent construction or landscaping during full flow discharge.

#### 3.4.11 Drains

Main drain piping shall be provided to discharge at a safe point onto a concrete splash block outside the building. Auxiliary drains shall be provided as required by NFPA 13. Drain valves shall be fully accessible and no higher than 7 feet above finish floor.

#### 3.4.12 Installation of Backflow Preventer Test Connection

Connection shall be mounted on the exterior wall approximately 3 feet above finished grade. Provide sleeves, seals and escutcheons at wall penetrations.

#### 3.4.13 Identification Signs

Signs shall 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. Hydraulic design data nameplates shall be engraved and permanently affixed to each sprinkler riser as specified in NFPA 13. Provide sign at FDC and at backflow preventer test connection.

### 3.5 UNDERGROUND PIPING INSTALLATION

The fire protection water main shall be laid, and joints anchored, in accordance with NFPA 24. Minimum depth of cover shall be 3 feet. The supply line shall terminate inside the building with a flanged piece, the bottom of which shall be set not less than 6 inches above the finished floor. A blind flange shall be installed temporarily on top of the flanged piece to prevent the entrance of foreign matter into the supply line. A concrete thrust block shall be provided at the elbow where the pipe turns up toward the floor. Buried steel components shall be provided with a corrosion protective coating in accordance with AWWA C203. Piping more than 5 feet outside the building walls shall meet the requirements of SAWS Requirements and Civil Drawings.

### 3.6 ELECTRICAL WORK

Except as modified herein, electric equipment and wiring shall be in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Alarm signal wiring connected to the building fire alarm control system shall be in accordance with Section 28 31 76 INTERIOR FIRE ALARM AND MASS NOTIFICATION SYSTEM. All wiring for supervisory and alarm circuits shall be #14 or #16 AWG solid copper installed in metallic tubing or conduit. Wiring color code shall remain uniform throughout the system.

### 3.7 PIPE COLOR CODE MARKING AND LABELING

Color code mark piping red as specified in Section 09 90 00 PAINTS AND COATINGS. Mark all exposed interior supply piping, mains and cross mains with plastic wrap-around type pipe labels conforming to MIL-STD-101 and ASME A13.1. Indicate type of fluid and direction of flow. Labels shall read: "FIRE PROTECTION WATER" for water supply piping, "FIRE SPRINKLER" for sprinkler piping, "FIRE DEPARTMENT CONNECTION" and "TEST." Mark valves with permanent tags indicating normally open or normally closed. Provide flow arrows on piping.

### 3.8 PRELIMINARY TEST PROCEDURES

The system, including the aboveground piping and system components, shall be flushed and tested to assure that equipment and components function as intended. Submit proposed procedures for Preliminary Tests, no later than 30 days prior to the proposed start of the tests and include proposed date and time to begin the Preliminary Tests. The aboveground interior piping systems and attached appurtenances subjected to system working pressure shall be flushed and tested in accordance with NFPA 13 and NFPA 24.

#### 3.8.1 Underground Piping

##### 3.8.1.1 Flushing

Underground piping shall be flushed in accordance with NFPA 24. This includes the requirement to flush the lead-in connection to the fire protection system at a flow rate not less than the calculated maximum water demand rate of the system.

##### 3.8.1.2 Hydrostatic Testing

New underground piping shall be hydrostatically tested in accordance with NFPA 24. The allowable leakage shall be measured at the specified test pressure by pumping from a calibrated container. The amount of leakage at the joints shall not exceed 2 quarts per hour per 100 gaskets or joints, regardless of pipe diameter.

##### 3.8.2.1 Hydrostatic Testing

Aboveground piping shall be hydrostatically tested in accordance with NFPA 13 at not less than the greater of 200 psi or 50 psi in excess of maximum system operating pressure and shall maintain that pressure without loss for 2 hours. There shall be no drop in gauge pressure or visible leakage when the system is subjected to the hydrostatic test. The test pressure shall 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 and Cross Connection Control Test

The backflow prevention assembly shall be tested at system flow demand, including all applicable hose streams, as specified in NFPA 13. Provide all equipment and instruments necessary to conduct a complete forward flow test, including 2.5 inch diameter hoses, playpipe nozzles, calibrated pressure gauges, pitot tube gauge, plus all necessary supports to safely secure hoses and nozzles during the test. At the system demand flow, the pressure readings and pressure drop (friction) across the assembly shall be recorded. Provide a metal placard 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. The pressure drop shall be compared to the manufacturer's data. Provide cross connection control testing in accordance with ASSE 1015. Provide forward flow test and cross connection control test reports with preliminary and final test reports.

### 3.8.3 Testing of Alarm Devices

Each alarm switch shall be tested by flowing water through the inspector's test connection. Each water-operated alarm device shall be tested to verify proper operation.

### 3.8.4 Main Drain Flow Test

Following flushing of the underground piping, a main drain test shall be made to verify the adequacy of the water supply. Static and residual pressures shall be recorded on the certificate specified in paragraph SUBMITTALS. In addition, a main drain test shall be conducted each time after a main control valve is shut and opened.

## 3.9 PRELIMINARY TEST REPORT

Upon completion of specified tests, submit 3 copies of the completed Preliminary Test Report, no later than 10 days after the completion of the Tests. The Report shall include the Contractor's Material and Test Certificate for Underground Piping, Contractor's Material and Test Certificates for Aboveground Piping, as well as the Cross Connection Control Certificates for Backflow Preventers and the sign-in sheet identifying test personnel and contact information. Include layout of the flushing of the underground. All items in the Preliminary Test Report shall be signed by the QFPE.

## 3.10 FINAL ACCEPTANCE TEST PROCEDURES

Begin the Final Acceptance Test only when the Preliminary Test Report has been approved. Submit proposed procedures for Final Acceptance Test, no later than 30 days prior to the proposed start of the tests. Submit proposed date and time to begin the Test with the procedures. Notification shall be provided at least 30 days prior to the proposed start of the test. Notification shall include a copy of the Contractor's Material & Test Certificates. The QFPE shall conduct the Final Acceptance Test and shall provide a complete demonstration of the operation of the system. This shall include operation of control valves and flowing of inspector's test connections to verify operation of associated waterflow alarm switches. After operation of control valves has been completed, the main drain test shall be repeated to assure that control valves are in the open position.

## 3.11 FINAL ACCEPTANCE TEST REPORT

The installation shall not be considered accepted until identified discrepancies have been corrected and test documentation is properly completed and received. Submit 3 copies of the completed Final Acceptance Test Report no later than 14 days after the completion of the Final Acceptance Tests. All items in the Final Acceptance Report shall be signed by the QFPE.

### 3.12 AS-BUILT SHOP DRAWINGS

Submit as-built shop drawings, 14 days after completion of the Final Tests, updated to reflect as-built conditions after all related work is completed. Drawings shall be on electronic media with two full size paper copies. In addition, during final testing, the representative shall have available paper copies of as-built drawings and Preliminary Test Report during final testing.

### 3.13 ONSITE TRAINING

The Fire Protection Specialist shall conduct a training course for operating and maintenance personnel as designated by the Contracting Officer. Submit proposed schedule, at least 14 days prior to the start of related training. Training shall be provided for a period of 2 hours of normal working time, divided into two shifts, and shall start after the system is functionally complete and after the Final Acceptance Test. As-built Shop Drawings and O&M Manuals shall be available during training.

### 3.14 OPERATING AND MAINTENANCE MANUALS

Submit 6 Operating and Maintenance Manuals and an electronic file listing step-by-step procedures required for system startup, operation, shutdown, and routine maintenance, at least 14 days prior to field training. Update manuals with changes made during acceptance testing. 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. Each service organization submitted shall be capable of providing 4 hour on-site response to a service call on an emergency basis. The Onsite Training shall cover all of the items contained in the approved manuals.

-- End of Section --

SECTION 22 00 00

PLUMBING, GENERAL PURPOSE  
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.

AIR-CONDITIONING, HEATING AND REFRIGERATION INSTITUTE (AHRI)

AHRI 1010 (2002) Self-Contained, Mechanically Refrigerated Drinking-Water Coolers

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

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

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

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

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME A112.1.2 (2012; R 2017) 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 (2019) Standard for Floor and Trench Drains

ASME A112.14.1 (2003; R 2017) Backwater Valves

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 (2017; Errata 2017) Stainless Steel Plumbing Fixtures

ASME A112.36.2M (1991; R 2017) 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	(2011) Cast Copper Alloy Solder Joint Drainage Fittings - DWV
ASME B16.24	(2011) Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 600, 900, 1500, and 2500
ASME B16.29	(2017) Wrought Copper and Wrought Copper Alloy Solder-Joint Drainage Fittings - DWV
ASME B16.39	(2014) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300
ASME B16.50	(2013) 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	(2016) Refrigeration Piping and Heat Transfer Components
ASME B40.100	(2013) 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 CSD-1	(2016) Control and Safety Devices for Automatically Fired Boilers

AMERICAN SOCIETY OF SANITARY ENGINEERING (ASSE)

ASSE 1001	(2016) Performance Requirements for Atmospheric Type Vacuum Breakers
ASSE 1003	(2009) Performance Requirements for Water Pressure Reducing Valves for Domestic Water Distribution Systems - (ANSI approved 2010)
ASSE 1010	(2004) Performance Requirements for Water Hammer Arresters (ANSI approved 2004)
ASSE 1011	(2004; Errata 2004) Performance Requirements for Hose Connection Vacuum Breakers (ANSI approved 2004)
ASSE 1012	(2009) Performance Requirements for Backflow Preventer with an Intermediate Atmospheric Vent - (ANSI approved 2009)
ASSE 1013	(2011) Performance Requirements for Reduced Pressure Principle Backflow Preventers and Reduced Pressure Fire Protection Principle Backflow Preventers - (ANSI approved 2010)
ASSE 1018	(2001) Performance Requirements for Trap Seal Primer Valves - Potable Water Supplied (ANSI Approved 2002)
ASSE 1019	(2011; R 2016) Performance Requirements for Wall Hydrant with Backflow Protection and Freeze Resistance
ASSE 1020	(2004; Errata 2004; Errata 2004) Performance Requirements for Pressure Vacuum Breaker Assembly (ANSI Approved 2004)

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA B300	(2010; Addenda 2011) Hypochlorites
AWWA B301	(2010) Liquid Chlorine
AWWA C203	(2020) Coal-Tar Protective Coatings and Linings for Steel Water Pipelines - Enamel and Tape - Hot-Applied
AWWA C219	(2017) Bolted Sleeve-Type Couplings for Plain-End Pipe
AWWA C606	(2015) Grooved and Shouldered Joints
AWWA C651	(2014) Standard for Disinfecting Water Mains
AWWA C652	(2011) Disinfection of Water-Storage

Facilities

AWWA C700 (2015) Cold-Water Meters - Displacement Type, Metal Alloy Main Case

AWWA C701 (2015) Cold-Water Meters - Turbine Type for Customer Service

AWWA D100 (2011) 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 Castings

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

ASTM A74 (2017) 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) 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 2018) Standard Specification for Corrosion-Resistant High-Silicon Iron Castings

ASTM A536 (1984; R 2019; E 2019) Standard Specification for Ductile Iron Castings

ASTM A733 (2016; R 2022) Standard Specification for

Welded and Seamless Carbon Steel and  
Austenitic Stainless Steel Pipe Nipples

ASTM A888	(2018) 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	(2015a) Standard Specification for Seamless Copper Pipe, Standard Sizes
ASTM B43	(2014) Standard Specification for Seamless Red Brass Pipe, Standard Sizes
ASTM B75/B75M	(2011) Standard Specification for Seamless Copper Tube
ASTM B88	(2016) Standard Specification for Seamless Copper Water Tube
ASTM B88M	(2018) Standard Specification for Seamless Copper Water Tube (Metric)
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	(2013) Standard Specification for Copper Drainage Tube (DWV)
ASTM B370	(2022) Standard Specification for Copper Sheet and Strip for Building Construction
ASTM B584	(2014) 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 B828	(2016) Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings
ASTM C564	(2014) 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 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 D2822/D2822M	(2005; R 2011; E 2011) Standard Specification for Asphalt Roof Cement, Asbestos-Containing
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	(1998; R 2011) Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals
ASTM D3212	(2007; R 2013) 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 E1	(2014) Standard Specification for ASTM Liquid-in-Glass Thermometers
ASTM F409	(2017) Standard Specification for Thermoplastic Accessible and Replaceable Plastic Tube and Tubular Fittings
ASTM F477	(2014; R 2021) Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
ASTM F493	(2014) Solvent Cements for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe and Fittings
ASTM F628	(2012; E 2013; E 2016; E 2018) Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe with a Cellular Core
ASTM F877	(2019) Standard Specification for Crosslinked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems
ASTM F891	(2016) 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) Standard Specification for Coextruded Poly(Vinyl Chloride) (PVC) Non-Pressure Plastic Pipe Having Reprocessed-Recycled Content
ASTM F2389	(2017a) Standard Specification for Pressure-rated Polypropylene (PP) Piping Systems

CAST IRON SOIL PIPE INSTITUTE (CISPI)

CISPI 301	(2012) 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 (2005b) Press Type Or Plain End Rub  
Gasketed W/ Nail CU & CU Alloy Fittings 4  
Install On CU Tubing

INTERNATIONAL CODE COUNCIL (ICC)

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

ICC IPC (2018) International Plumbing Code

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-44 (2017) Steel Pipeline Flanges

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

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-83 (2014) Class 3000 Steel Pipe Unions Socket  
Welding and Threaded

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

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 90A (2021) Standard for the Installation of Air Conditioning and Ventilating Systems

NSF INTERNATIONAL (NSF)

NSF 372 (2016) Drinking Water System Components - Lead Content

NSF/ANSI 14 (2018) Plastics Piping System Components and Related Materials

NSF/ANSI 61 (2019) 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

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE J1508 (2009) 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)

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

UNDERWRITERS LABORATORIES (UL)

UL 430 (2015; Reprint Feb 2018) UL Standard for Safety Waste Disposers

## 1.2 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. 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

Fixtures

List of installed fixtures with manufacturer, model, and flow rate.

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

Drinking-Water Coolers; G

Energy Star Label for Electric Water Cooler; S

Water Heaters; G

Pumps; G

Backflow Prevention Assemblies; G

Welding

A copy of qualified procedures and a list of names and identification symbols of qualified welders and welding operators.

Plumbing System

Diagrams, instructions, and other sheets proposed for posting. Manufacturer's recommendations for the installation of bell and

spigot and hubless joints for cast iron soil pipe.

#### SD-06 Test Reports

Tests, Flushing and Disinfection; G

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 shall indicate the final position of controls.

Test of Backflow Prevention Assemblies; G.

Certification of proper operation shall 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 shall have the manufacturer's representative test the device, to ensure the unit is properly installed and performing as intended. The Contractor shall provide written documentation of the tests performed and signed by the individual performing the tests.

#### SD-07 Certificates

Materials and Equipment; G

Where equipment is specified to conform to requirements of the ASME Boiler and Pressure Vessel Code, the design, fabrication, and installation shall conform to the code.

Bolts; G

Written certification by the bolt manufacturer that the bolts furnished comply with the specified requirements.

#### SD-10 Operation and Maintenance Data

Plumbing System; G

Water Heaters; G

Pumps; G

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

### 1.3 STANDARD PRODUCTS

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

### 1.3.1 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.

### 1.3.2 Service Support

The equipment items shall 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 shall 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.

### 1.3.3 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.

### 1.3.4 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.

#### 1.3.4.1 Definitions

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

#### 1.3.4.2 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, shall 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 PERFORMANCE REQUIREMENTS

### 1.5.1 Welding

Piping shall be welded in accordance with qualified procedures using performance-qualified welders and welding operators. Procedures and welders shall 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. The Contracting Officer shall be notified 24 hours in advance of tests, and the tests shall be performed at the work site if practicable. Welders or welding operators shall apply their assigned symbols near each weld they make as a permanent record.

## 1.6 REGULATORY REQUIREMENTS

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

## 1.7 PROJECT/SITE CONDITIONS

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

## 1.8 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 shall be thoroughly familiar with all parts of the installation and shall be trained in operating theory as well as practical operation and maintenance work.

Instruction shall 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 shall 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.

## 1.9 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 PRODUCT SUSTAINABILITY CRITERIA

For products in this section, where applicable and to extent allowed by performance criteria, provide and document the following:

#### 2.1.1 Water Efficient Products

Provide documentation in conformance with Section 01 33 29 SUSTAINABILITY REPORTING that the following products meet water efficiency requirements as outlined in this section and when applicable, that they are EPA WaterSense labeled products:

- a. Fixtures
- b. Flush valve water closets
- c. Flush valve urinals
- d. Wall hung lavatories
- e. Countertop lavatories
- f. Kitchen sinks
- g. Service sinks
- h. Drinking-water coolers
- i. Water Heaters
- j. Pumps

### 2.2 MATERIALS

Materials for various services shall be in accordance with TABLES I and II. Pipe schedules shall be selected based on service requirements. Pipe fittings shall be compatible with the applicable pipe materials. Plastic pipe, fittings, and solvent cement shall meet NSF/ANSI 14 and shall be NSF listed for the service intended. Plastic pipe, fittings, and solvent cement used for potable hot and cold water service shall bear the NSF seal "NSF-PW." Polypropylene pipe and fittings shall conform to dimensional requirements of Schedule 40, Iron Pipe size and shall comply with NSF/ANSI 14, NSF/ANSI 61 and ASTM F2389. Polypropylene piping that will be exposed to UV light shall be provided with a Factory applied UV resistant coating. Pipe threads (except dry seal) shall conform to ASME B1.20.1. Grooved pipe couplings and fittings shall be from the same manufacturer. Material or equipment containing a weighted average of greater than 0.25 percent lead shall not be used in any potable water system intended for human consumption, and shall be certified in accordance with NSF/ANSI 61, Annex G or NSF 372. In line devices such as water meters, building valves, check valves, meter stops, valves, fittings and back flow preventers shall 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 shall not be installed underground, under concrete floor slabs, or in crawl spaces below kitchen floors. Plastic pipe shall not be installed in air plenums. Plastic pipe shall not be installed in a pressure piping system in buildings greater than three stories including any basement levels.

#### 2.2.1 Pipe Joint Materials

Grooved pipe and hubless cast-iron soil pipe shall not be used underground. Solder containing lead shall not be used with copper pipe. Cast iron soil pipe and fittings shall be marked with the collective

trademark of the Cast Iron Soil Institute. Joints and gasket materials shall 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) ..
- d. Flange Gaskets: Gaskets shall be made of non-asbestos material in accordance with ASME B16.21. Gaskets shall be flat, 1/16 inch thick, and contain Aramid fibers bonded with Styrene Butadiene Rubber (SBR) or Nitro Butadiene Rubber (NBR). Gaskets shall be the full face or self centering flat ring type. Gaskets used for hydrocarbon service shall be bonded with NBR.
- e. Brazing Material: Brazing material shall conform to AWS A5.8/A5.8M, BCuP-5.
- f. Brazing Flux: Flux shall be in paste or liquid form appropriate for use with brazing material. Flux shall 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 shall conform to ASTM B32.
- h. Solder Flux: Flux shall 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 shall be in accordance with ASME B16.5 class 150 and shall have the manufacturer's trademark affixed in accordance with MSS SP-25. Flange material shall conform to ASTM A105/A105M. Blind

flange material shall conform to ASTM A516/A516M cold service and ASTM A515/A515M for hot service. Bolts shall be high strength or intermediate strength with material conforming to ASTM A193/A193M.

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

#### 2.2.2 Miscellaneous Materials

Miscellaneous materials shall conform to the following:

- a. Water Hammer Arrester: PDI WH 201. Water hammer arrester shall be diaphragm or piston type.
- b. Copper, Sheet and Strip for Building Construction: ASTM B370.
- c. Asphalt Roof Cement: ASTM D2822/D2822M.
- 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 shall 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 shall not be used in thermometers.

#### 2.2.3 Pipe Insulation Material

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

#### 2.2.4 Pressure Transition Couplings

Pressure transition couplings for plastic (PVC/ABS) pressure pipe to ductile iron, copper or steel pressure pipe shall conform to the requirements of AWWA C219.

- a. Description: Metal sleeve-type same size as with pressure rating equal or greater than the pipes to be jointed. Ends shall be compatible with the pipes to be joined .
- b. Center-Sleeve Material: Manufacturer's standard for the application and pressure ratings.
- c. Gasket Material: Natural or synthetic rubber.
- d. Metal Component Finish: Corrosion-resistant coating or material.
- e. Compatibility: All pressure coupling components shall be fully compatible with the fluid material contained in the piping system.

#### 2.2.5 Nonpressure Transition Couplings

Shielded nonpressure transition couplings for plastic (PVC/ABS) nonpressure pipe to cast iron nonpressure pipe shall conform to the requirements.

- a. Description: Elastomeric or rubber sleeve with full-length, stainless steel outer shield and stainless steel tension band and tightening mechanism on each end. Ends shall be compatible with the pipes to be joined.
- b. Compatibility: All nonpressure coupling components shall be fully compatible with the fluid material contained in the piping system.

#### 2.2.6 ABS to PVC Plastic Pipe Transition Coupling

ABS to PVC plastic pipe transition coupling shall utilize a stainless steel jacket with duplex stainless steel adjustable tension bands installed over a rubber connection sleeve. Solvent welding of ABS pressure pipe to PVC pressure pipe is not acceptable.

### 2.3 PIPE HANGERS, INSERTS, AND SUPPORTS

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

### 2.4 VALVES

Valves shall be provided on supplies to equipment and fixtures. Valves 2-1/2 inches and smaller shall be bronze with threaded bodies for pipe and solder-type connections for tubing. Valves 3 inches and larger shall have flanged iron bodies and bronze trim. Pressure ratings shall 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 shall conform to the following standards:

Description	Standard
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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
Backwater Valves	ASME A112.14.1
Vacuum Relief Valves	ANSI Z21.22/CSA 4.4
Water Pressure Reducing Valves	ASSE 1003
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

2.4.1 Backwater Valves

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

2.4.2 Wall Faucets

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

#### 2.4.3 Wall Hydrants (Frostproof)

ASSE 1019 with vacuum-breaker backflow preventer shall have a nickel-brass or nickel-bronze wall plate or flange with nozzle and detachable key handle. A brass or bronze operating rod shall 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 shall be provided. Valve rod and seat washer shall be removable through the face of the hydrant. The hydrant shall have 3/4 inch exposed hose thread on spout and 3/4 inch male pipe thread on inlet.

#### 2.4.4 Lawn Faucets

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

#### 2.4.5 Yard Hydrants

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

#### 2.4.6 Relief Valves

Water heaters and hot water storage tanks shall have a combination pressure and temperature (P&T) relief valve. The pressure relief element of a P&T relief valve shall 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 shall have a relieving capacity which is at least equal to the total input of the heaters when operating at their maximum capacity. Relief valves shall 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 shall 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 shall have 1 inch minimum inlets, and 1 inch outlets. The discharge pipe from the relief valve shall be the size of the valve outlet.

#### 2.4.7 Thermostatic Mixing Valves

Provide thermostatic mixing valve for lavatory faucets. Mixing valves, thermostatic type, pressure-balanced or combination thermostatic and pressure-balanced shall be line size and shall be constructed with rough or finish bodies either with or without plating. Each valve shall 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 shall be of an approved type. The body shall be of heavy cast bronze, and interior parts shall be brass, bronze, corrosion-resisting steel or copper. The valve shall be equipped with necessary stops, check valves, unions, and sediment strainers on the inlets. Mixing valves shall maintain water temperature within 5 degrees F of any setting.

## 2.5 FIXTURES

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 shall be in accordance with ICC A117.1 COMM. Vitreous China, nonabsorbent, hard-burned, and vitrified throughout the body shall be provided. Porcelain enameled ware shall 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 shall 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, shall be equipped with a trap. Brass expansion or toggle bolts capped with acorn nuts shall be provided for supports, and polished chromium-plated pipe, valves, and fittings shall be provided where exposed to view. Fixtures with the supply discharge below the rim shall 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 shall be copper alloy with all visible surfaces chrome plated. Plastic in contact with hot water shall be suitable for 180 degrees F water temperature.

### 2.5.1 Automatic Controls

Flushing and faucet systems shall consist of solenoid-activated valves with light beam sensors. Flush valve for water closet shall include an override pushbutton. Flushing devices shall be provided as described in paragraph FIXTURES AND FIXTURE TRIMMINGS.

### 2.5.2 Flush Valve Water Closets

ASME A112.19.2/CSA B45.1, white vitreous china, siphon jet, elongated bowl, floor-mounted, floor outlet. Top of toilet seat height above floor shall 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 open-front seat.

Water flushing volume of the water closet and flush valve combination shall not exceed 1.28 gallons per flush. Water closets must meet the EPA WaterSense product definition specified in [http://www.epa.gov/watersense/partners/product\\_program\\_specs.html](http://www.epa.gov/watersense/partners/product_program_specs.html) and must be EPA WaterSense labeled products. Provide data identifying WaterSense label for flush valve water closet.

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

### 2.5.3 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. Water

flushing volume of the urinal and flush valve combination shall not exceed 0.5 gallons per flush. Urinals must meet the specifications of [http://www.epa.gov/watersense/partners/product\\_program\\_specs.html](http://www.epa.gov/watersense/partners/product_program_specs.html) and must be EPA WaterSense labeled products. Provide data identifying WaterSense label for urinal. 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 shall be chromium-plated or polished stainless steel. Flush valves shall be nonhold-open type. Mount flush valves not less than 11 inches above the fixture. Provide solenoid-activated flush valves including electrical-operated light-beam-sensor to energize the solenoid.

#### 2.5.4 Wall Hung Lavatories

ASME A112.19.2/CSA B45.1, white vitreous china, ,straight back type, minimum dimensions of 19 inches, wide by 17 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. Water flow rate shall not exceed 0.5 gpm when measured at a flowing water pressure of 60 psi. Lavatory faucets and lavatory faucet accessories must meet EPA WaterSense product definition specified in <http://www.epa.gov/watersense/partners/productprogramspe.html> and must be EPA WaterSense labeled products. 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 solenoid-activated lavatory faucets including electrical-operated light-beam-sensor to energize the solenoid.

#### 2.5.5 Countertop Lavatories

ASME A112.19.2/CSA B45.1, white vitreous china, ,self-rimming, 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. Water flow rate shall not exceed 0.5 gpm when measured at a flowing water pressure of 60 psi. Lavatory faucets and lavatory faucet accessories must meet the EPA WaterSense product definition specified in <http://www.epa.gov/watersense/partners/productprogramspe.html> and must be EPA WaterSense labeled products. 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 solenoid-activated lavatory faucets including electrical-operated light-beam-sensor to energize the solenoid.

#### 2.5.6 Kitchen Sinks

ASME A112.19.3/CSA B45.4, 20 gage stainless steel with integral mounting rim for flush installation, minimum dimensions of 33 inches wide by 21 inches front to rear, two compartments, 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 shall 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. Provide UL 430 waste disposer where scheduled on the drawings.

## 2.5.7 Drinking-Water Coolers

AHRI 1010 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, 4.75 gph minimum capacity, stainless steel splash receptor and basin, bottle filler and stainless steel cabinet. Bubblers shall be controlled by push levers or push bars, front mounted or side mounted near the front edge of the cabinet. Bubbler spouts shall be mounted at maximum of 36 inches above floor and at front of unit basin. Spouts shall direct water flow at least 4 inches above unit basin and trajectory parallel or nearly parallel to the front of unit. Provide ASME A112.6.1M concealed steel pipe chair carriers. Provide electric water cooler that is Energy Star labeled. Provide data identifying Energy Star label for electric water cooler.

## 2.5.8 Precast Terrazzo Mop Sinks

Terrazzo shall 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. Provide chrome plated service sink faucet with vacuum breakers, integral stops, adjustable wall brace, pail hook and 3/4 inch hose thread on spout. provide 5/8 inch heavy duty rubber hose cloth reinforced with 3/4 inch brass coupling at one end. Provide stainless steel hose bracket. Provide stainless steel mop hanger with three (3) rubber tool grips.

## 2.6 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 shall be meet the above requirements.

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

## 2.7 DRAINS

### 2.7.1 Floor Drains

Floor drains shall 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 shall be cast iron except where metallic waterproofing membrane is installed. Drains shall be of double drainage pattern for embedding in the floor construction. The seepage pan shall have weep holes or channels

for drainage to the drainpipe. The strainer shall 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 shall be provided when required. Drains shall 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 shall conform to ASME A112.6.3. Provide drain with trap primer connection, trap primer, and connection piping. Primer shall meet ASSE 1018.

#### 2.7.1.1 Drains and Backwater Valves

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

#### 2.7.2 Floor Sinks

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

#### 2.8 TRAPS

Unless otherwise specified, traps shall be plastic per ASTM F409 or copper-alloy adjustable tube type with slip joint inlet and swivel. Traps shall be without a cleanout. Provide traps with removable access panels for easy clean-out at sinks and lavatories. Tubes shall 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 shall have rubber washer and copper alloy nuts for slip joints above the discharge level. Swivel joints shall be below the discharge level and shall be of metal-to-metal or metal-to-plastic type as required for the application. Nuts shall have flats for wrench grip. Outlets shall have internal pipe thread, except that when required for the application, the outlets shall have sockets for solder-joint connections. The depth of the water seal shall be not less than 2 inches. The interior diameter shall be not more than 1/8 inch over or under the nominal size, and interior surfaces shall 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 shall be provided for lavatories. The assembly shall be a standard manufactured unit and may have a rubber-gasketed swivel joint.

#### 2.9 WATER HEATERS

Refer to Section 23 52 00, Heating Boilers for brazed plate type heat exchangers utilized for domestic hot water production.

#### 2.10 HOT-WATER STORAGE TANKS

Hot-water storage tanks shall be constructed by one manufacturer, ASME stamped for the working pressure, and shall have the National Board (ASME) registration. The tank shall be cement-lined or glass-lined steel type in

accordance with AWWA D100. The heat loss shall conform to TABLE III in PART 3 of this Section as determined by the requirements of ASHRAE 90.1 - IP. Each tank shall 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 shall have a separable socket suitable for a 3/4 inch tapped opening. Tanks shall be equipped with a pressure gauge 6 inch minimum diameter face. Insulation shall be as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. Storage tank capacity shall be as shown.

## 2.11 PUMPS

### 2.11.1 Circulating Pumps

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

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

## 2.12 WATER PRESSURE BOOSTER SYSTEM

### 2.12.1 Variable Speed Pumping System

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

## 2.13 DOMESTIC WATER SERVICE METER

Cold water meters 2 inches and smaller shall be positive displacement type conforming to AWWA C700. Cold water meters 2-1/2 inches and larger shall be turbine type conforming to AWWA C701. Meter register may be round or straight reading type, with electronic register and fully programmable. Meter shall be provided with a pulse generator, remote readout register

and all necessary wiring and accessories as scheduled on the drawings.

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.

#### 2.14 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.

Motors shall be rated for continuous duty with the enclosure specified. Motor duty requirements shall allow for maximum frequency start-stop operation and minimum encountered interval between start and stop. Motor torque shall 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 shall be fitted with grease supply fittings and grease relief to outside of the enclosure.

Controllers and contactors shall 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, shall be provided. For packaged equipment, the manufacturer shall provide controllers, including the required monitors and timed restart.

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

#### 2.15 MISCELLANEOUS PIPING ITEMS

##### 2.15.1 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.

##### 2.15.2 Pipe Sleeves

Provide where piping passes entirely through walls, ceilings, roofs, and floors. Sleeves are not required where drain, waste, and vent (DWV) piping passes through concrete floor slabs located on grade, except where penetrating a membrane waterproof floor.



#### 2.15.2.1 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.

#### 2.15.2.2 Sleeves Not in Masonry and Concrete

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

#### 2.15.3 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.

#### 2.15.4 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 shall 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.

#### 2.15.5 Labels

Provide labels for sensor operators at flush valves and faucets. Include the following information on each label:

- a. Identification of the sensor and its operation with written description.
- b. Range of the sensor.
- c. Battery replacement schedule.

### PART 3 EXECUTION

#### 3.1 GENERAL INSTALLATION REQUIREMENTS

Piping located in air plenums shall conform to NFPA 90A requirements. Piping located in shafts that constitute air ducts or that enclose air ducts shall 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 shall be installed complete with necessary fixtures, fittings, traps, valves, and accessories. Water and drainage piping shall be extended 5 feet outside the building, unless otherwise indicated. A full port ball valve and

drain shall be installed on the water service line inside the building approximately 6 inches above the floor from point of entry. Piping shall be connected to the exterior service lines or capped or plugged if the exterior service is not in place. Sewer and water pipes shall be laid in separate trenches, except when otherwise shown. Exterior underground utilities shall 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 shall be marked with a stake or other acceptable means. Valves shall be installed with control no lower than the valve body.

### 3.1.1 Water Pipe, Fittings, and Connections

#### 3.1.1.1 Utilities

The piping shall be extended to fixtures, outlets, and equipment. The hot-water and cold-water piping system shall 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, shall 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 shall be anchored to prevent movement.

#### 3.1.1.2 Cutting and Repairing

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

#### 3.1.1.3 Protection of Fixtures, Materials, and Equipment

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

#### 3.1.1.4 Mains, Branches, and Runouts

Piping shall be installed as indicated. Pipe shall be accurately cut and worked into place without springing or forcing. Structural portions of the building shall not be weakened. Aboveground piping shall 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 shall 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 shall 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 shall not be buried in or under floors unless specifically indicated or approved. Changes in pipe sizes shall 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 shall 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 shall 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 shall 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 shall be provided. Disconnection of the supply piping at the fixture is an acceptable drain.

#### 3.1.1.6 Expansion and Contraction of Piping

Allowance shall be made throughout for expansion and contraction of water pipe. Each hot-water and hot-water circulation riser shall have expansion loops or other provisions such as offsets and changes in direction where indicated and required. Risers shall be securely anchored as required or where indicated to force expansion to loops. Branch connections from risers shall 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 shall be anchored to the wall or the supporting construction about midway on the run to force expansion, evenly divided, toward the ends. Sufficient flexibility shall be provided on branch runouts from mains and risers to provide for expansion and contraction of piping. Flexibility shall 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 shall be provided with thrust blocks, where indicated, to prevent movement. Thrust blocking shall 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 shall be placed between solid ground and the fitting to be anchored. Unless otherwise indicated or directed, the base and thrust bearing sides of the thrust block shall be poured against undisturbed earth. The side of the thrust block not subject to thrust shall be poured against forms. The area of bearing will be as shown. Blocking shall 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, shall 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 shall be provided on hot- and cold-water supplies and shall be located as generally indicated, with precise location and sizing to be in accordance with PDI WH 201. Water hammer arresters, where concealed, shall be accessible by means of access doors or removable panels. Commercial-type water hammer arresters shall conform to ASSE 1010. Vertical capped pipe columns will not be permitted.

### 3.1.2 Joints

Installation of pipe and fittings shall 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 shall be made up with fittings of compatible material and made for the specific purpose intended.

#### 3.1.2.1 Threaded

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

#### 3.1.2.2 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.

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 shall 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.

Grooved fittings and couplings, and grooving tools shall be provided from the same manufacturer. Segmentally welded elbows shall not be used. Grooves shall be prepared in accordance with the coupling manufacturer's latest published standards. Grooving shall be performed by qualified grooving operators having demonstrated proper grooving procedures in accordance with the tool manufacturer's recommendations.

The Contracting Officer shall be notified 24 hours in advance of test to demonstrate operator's capability, and the test shall be performed at the work site, if practical, or at a site agreed upon. The operator shall 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.

#### 3.1.2.3 Unions and Flanges

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

#### 3.1.2.4 Grooved Mechanical Joints

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 and recorded for each change in grooving tool setup to verify compliance with coupling manufacturer's tolerances. Grooved joints shall not be used in concealed locations.

#### 3.1.2.5 Cast Iron Soil, Waste and Vent Pipe

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

#### 3.1.2.6 Copper Tube and Pipe

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

#### 3.1.2.7 Plastic Pipe

Acrylonitrile-Butadiene-Styrene (ABS) pipe shall have joints made with solvent cement. PVC and CPVC pipe shall 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.

#### 3.1.2.8 Glass Pipe

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

#### 3.1.2.9 Corrosive Waste Plastic Pipe

Joints for polyolefin pipe and fittings shall 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

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

#### 3.1.2.10 Polypropylene Pipe

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

#### 3.1.2.11 Other Joint Methods

#### 3.1.3 Dissimilar Pipe Materials

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

#### 3.1.4 Corrosion Protection for Buried Pipe and Fittings

Ductile iron, cast iron, and steel pipe, fittings, and joints shall have a protective coating. Additionally, ductile iron, cast iron, and steel pressure pipe shall have a cathodic protection system and joint bonding. The cathodic protection system, protective coating system, and joint bonding for cathodically protected pipe shall be in accordance with Section 26 42 14.0 10, CATHODIC PROTECTION SYSTEM (SACRIFICIAL ANODE) . Coatings shall be selected, applied, and inspected in accordance with NACE SP0169 and as otherwise specified. The pipe shall be cleaned and the coating system applied prior to pipe tightness testing. Joints and fittings shall be cleaned and the coating system applied after pipe tightness testing. For tape coating systems, the tape shall conform to AWWA C203 and shall be applied with a 50 percent overlap. Primer utilized with tape type coating systems shall be as recommended by the tape manufacturer.

#### 3.1.5 Pipe Sleeves and Flashing

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

##### 3.1.5.1 Sleeve Requirements

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

Secure sleeves in position and location during construction. Provide sleeves of sufficient length to pass through entire thickness of walls, ceilings, roofs, and floors.

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 shall 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 shall 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 shall cause the rubber sealing elements to expand and provide a watertight seal between the pipe and the sleeve. Each seal assembly shall be sized as recommended by the manufacturer to fit the pipe and sleeve involved.

Sleeves shall not be installed in structural members, except where indicated or approved. Rectangular and square openings shall be as detailed. Each sleeve shall extend through its respective floor, or roof, and shall 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 shall extend a minimum of 4 inches above the finished floor.

Unless otherwise indicated, sleeves shall be of a size to provide a minimum of 1/4 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 shall 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.

Except as otherwise specified, the annular space between pipe and sleeve, or between jacket over insulation and sleeve, shall 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 shall not be sealed for interior walls which are not designated as fire rated.

Sleeves through below-grade walls in contact with earth shall be recessed 1/2 inch from wall surfaces on both sides. Annular space between pipe and sleeve shall be filled with backing material and sealants in the joint between the pipe and masonry wall as specified above. Sealant selected for the earth side of the wall shall be compatible with dampproofing/waterproofing materials that are to be applied over the joint sealant. Pipe sleeves in fire-rated walls shall conform to the requirements in Section 07 84 00 FIRESTOPPING.

### 3.1.5.2 Flashing Requirements

Pipes passing through roof shall be installed through a 16 ounce copper flashing, each within an integral skirt or flange. Flashing shall be suitably formed, and the skirt or flange shall extend not less than 8 inches from the pipe and shall be set over the roof or floor membrane in a solid coating of bituminous cement. The flashing shall extend up the pipe a minimum of 10 inches. For cleanouts, the flashing shall be turned down into the hub and caulked after placing the ferrule. Pipes passing through pitched roofs shall 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 shall be sealed as indicated. Flashing for dry vents shall 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 shall be fitted into the sleeve clamping device. Pipes passing through wall waterproofing membrane shall be sleeved as described above. A waterproofing clamping flange shall be installed.

#### 3.1.5.3 Waterproofing

Waterproofing at floor-mounted water closets shall be accomplished by forming a flashing guard from soft-tempered sheet copper. The center of the sheet shall 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 shall be embedded in sealant to a depth of approximately 1-1/2 inches; then the sealant shall be finished off flush to floor level between the flashing guard and drainpipe. The flashing guard of sheet copper shall extend not less than 8 inches from the drainpipe and shall 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 shall be sealed with sealant and the flashing guard shall 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 shall be sealed.

#### 3.1.5.4 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.

#### 3.1.5.5 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 shall be formed around the pipe, fitting or drain. The groove shall be filled with a sealant as specified in Section 07 92 00 JOINT SEALANTS.

#### 3.1.5.6 Pipe Penetrations

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

#### 3.1.6 Fire Seal

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



### 3.1.7 Supports

#### 3.1.7.1 General

Hangers used to support piping 2 inches and larger shall be fabricated to permit adequate adjustment after erection while still supporting the load. Pipe guides and anchors shall 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 shall 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 shall be used where each pipe crosses the base support member. Spacing of the base support members shall not exceed the hanger and support spacing required for an individual pipe in the multiple pipe run. Threaded sections of rods shall not be formed or bent.

#### 3.1.7.2 Pipe Supports and Structural Bracing, Seismic Requirements

Piping and attached valves shall be supported and braced to resist seismic loads as specified in Section 23 05 48.19 SEISMIC BRACING FOR HVAC. Structural steel required for reinforcement to properly support piping, headers, and equipment, but not shown, shall be provided.

#### 3.1.7.3 Pipe Hangers, Inserts, and Supports

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

- a. Types 5, 12, and 26 shall not be used.
- b. Type 3 shall not be used on insulated pipe.
- c. Type 18 inserts shall 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 shall be torqued per MSS SP-58 and shall 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 shall 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 shall be used on insulated pipe 4 inches and larger when the temperature of the medium is 60 degrees F or higher. Type 39 saddles shall be welded to the pipe.
- h. Type 40 shields shall:
  - (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 shall have a density of 8 pcf or greater.
- i. Horizontal pipe supports shall be spaced as specified in MSS SP-58 and a support shall be installed not over 1 foot from the pipe fitting joint at each change in direction of the piping. Pipe supports shall be spaced not over 5 feet apart at valves. Operating temperatures in determining hanger spacing for PVC or CPVC pipe shall be 120 degrees F for PVC and 180 degrees F for CPVC. Horizontal pipe runs shall include allowances for expansion and contraction.
  - j. Vertical pipe shall 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 shall include allowances for expansion and contraction.
  - k. Type 35 guides using steel, reinforced polytetrafluoroethylene (PTFE) or graphite slides shall be provided to allow longitudinal pipe movement. Slide materials shall be suitable for the system operating temperatures, atmospheric conditions, and bearing loads encountered. Lateral restraints shall 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 shall be the size of the outside diameter of the insulation. The insulation shall 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 shall include a pipe cradle, welded to the guide structure and strapped securely to the pipe. The pipe shall 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 shall not compress, distort, cut or abrade the piping, and shall allow free movement of pipe except where otherwise required in the control of expansion/contraction.

#### 3.1.7.4 Structural Attachments

Attachment to building structure concrete and masonry shall be by cast-in concrete inserts, built-in anchors, or masonry anchor devices. Inserts and anchors shall be applied with a safety factor not less than 5. Supports shall not be attached to metal decking. Supports shall 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 shall be constructed of ferrous materials only.

### 3.1.8 Welded Installation

Plumbing pipe weldments shall be as indicated. Changes in direction of piping shall 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 shall 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 shall conform to ASME B31.1. Weld defects shall be removed and repairs made to the weld, or the weld joints shall be entirely removed and rewelded. After filler metal has been removed from its original package, it shall 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 shall not be used.

### 3.1.9 Pipe Cleanouts

Pipe cleanouts shall 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 shall 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 shall be caulked into the hub of the fitting and shall be flush with the floor. Cleanouts in connection with other pipe, where indicated, shall be T-pattern, 90-degree branch drainage fittings with cast-brass screw plugs, except plastic plugs shall be installed in plastic pipe. Plugs shall be the same size as the pipe up to and including 4 inches. Cleanout tee branches with screw plug shall 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 shall be provided with chromium plated bronze, nickel bronze, nickel brass or stainless steel flush type access cover plates. Round access covers shall 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 shall have access covers and frames installed flush with the finished wall. Cleanouts installed in finished floors subject to foot traffic shall 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 shall not project above the cover surface. Where cleanouts are provided with adjustable heads, the heads shall be cast iron.

## 3.2 WATER HEATERS AND HOT WATER STORAGE TANKS

### 3.2.1 Heat Traps

Piping to and from domestic hot water brazed plate heat exchanger and hot water storage tank shall be routed horizontally and downward a minimum of 2 feet before turning in an upward direction.

### 3.2.2 Connections to Domestic Hot Water Brazed Plate Heat Exchanger

Connections of metallic pipe to domestic hot water brazed plate heat exchanger shall be made with dielectric unions or flanges.

### 3.2.3 Expansion Tank

A pre-charged expansion tank shall be installed on the cold water supply between the water heater inlet and the cold water supply shut-off valve. The Contractor shall 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 shall 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 shall be furnished and installed with fixtures. Where connections between copper tubing and faucets are made by rubber compression fittings, a beading tool shall be used to mechanically deform the tubing above the compression fitting. Exposed traps and supply pipes for fixtures and equipment shall be connected to the rough piping systems at the wall, unless otherwise specified under the item. Floor and wall escutcheons shall be as specified. Drain lines and hot water lines of fixtures for handicapped personnel shall be insulated and do not require polished chrome finish. Plumbing fixtures and accessories shall 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 shall be provided. Connections between earthenware fixtures and flanges on soil pipe shall 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 shall 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 shall be secured to prevent movement by anchoring the long finished top spud connecting tube to wall adjacent to valve with approved metal bracket.

#### 3.3.3 Height of Fixture Rims Above Floor

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

#### 3.3.4 Fixture Supports

Fixture supports for off-the-floor lavatories, urinals, water closets, and other fixtures of similar size, design, and use, shall be of the chair-carrier type. The carrier shall provide the necessary means of mounting the fixture, with a foot or feet to anchor the assembly to the floor slab. Adjustability shall be provided to locate the fixture at the desired height and in proper relation to the wall. Support plates, in lieu of chair carrier, shall be fastened to the wall structure only where

it is not possible to anchor a floor-mounted chair carrier to the floor slab.

#### 3.3.4.1 Support for Solid Masonry Construction

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

#### 3.3.4.2 Support for Concrete-Masonry Wall Construction

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

#### 3.3.4.3 Support for Steel Stud Frame Partitions

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

#### 3.3.4.4 Support for Wood Stud Construction

Where floor is a concrete slab, a floor-anchored chair carrier shall be used. Where entire construction is wood, wood crosspieces shall be installed. Fixture hanger plates, supports, brackets, or mounting lugs shall 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 shall extend the full width of the fixture and shall be securely supported.

#### 3.3.4.5 Wall-Mounted Water Closet Gaskets

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

#### 3.3.5 Backflow Prevention Devices

Plumbing fixtures, equipment, and pipe connections shall not cross connect or interconnect between a potable water supply and any source of nonpotable water. Backflow preventers shall be installed where indicated and in accordance with 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 shall 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 shall be located so that no part of the device will be submerged. Backflow preventers shall 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 shall not be provided around backflow preventers. Access shall be provided for maintenance and testing. Each device shall be a standard commercial unit.

### 3.3.6 Access Panels

Access panels shall be provided for concealed valves and controls, or any item requiring inspection or maintenance. Access panels shall be of sufficient size and located so that the concealed items may be serviced, maintained, or replaced.

### 3.3.7 Traps

Each trap shall be placed as near the fixture as possible, and no fixture shall be double-trapped. Traps installed on cast-iron soil pipe shall be cast iron. Traps installed on steel pipe or copper tubing shall 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 shall be of the same material as the pipe.

## 3.4 WATER METER REMOTE READOUT REGISTER

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

## 3.5 IDENTIFICATION SYSTEMS

### 3.5.1 Identification Tags

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

### 3.5.2 Pipe Color Code Marking

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

### 3.5.3 Color Coding Scheme for Locating Hidden Utility Components

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

shall be mounted and located in the mechanical or equipment room.  
Contractor shall submit a color code system scheme for Government approval.

### 3.6 ESCUTCHEONS

Escutcheons shall 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 shall be fastened securely to pipe or pipe covering and shall be satin-finish, corrosion-resisting steel, polished chromium-plated zinc alloy, or polished chromium-plated copper alloy. Escutcheons shall be either one-piece or split-pattern, held in place by internal spring tension or setscrew.

### 3.7 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.

#### 3.7.1 Painting of New Equipment

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

##### 3.7.1.1 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 shall withstand 500 hours in a salt-spray fog test. Salt-spray fog test shall be in accordance with ASTM B117, and for that test the acceptance criteria shall be as follows: immediately after completion of the test, the paint shall show no signs of blistering, wrinkling, or cracking, and no loss of adhesion; and the specimen shall 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 shall 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 shall be designed for the temperature service.

##### 3.7.1.2 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 shall 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 shall 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 shall

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 shall 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 shall receive two coats of 600 degrees F heat-resisting paint applied to a total minimum dry film thickness of 2 mils.

### 3.8 TESTS, FLUSHING AND DISINFECTION

#### 3.8.1 Plumbing System

The following tests shall be performed on the plumbing system in accordance with , except that the drainage and vent system final test shall 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 shall include a smoke test.
- b. Building Sewers Tests.
- c. Water Supply Systems Tests.

##### 3.8.1.1 Test of Backflow Prevention Assemblies

Backflow prevention assembly shall be tested using gauges specifically designed for the testing of backflow prevention assemblies.

Backflow prevention assembly test gauges shall 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 shall 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 shall 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 shall be repaired and retested.

### 3.8.2 Defective Work

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

### 3.8.3 System Flushing

#### 3.8.3.1 During Flushing

Before operational tests or disinfection, potable water piping system shall be flushed with potable water. Sufficient water shall 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) shall specify the number of fixtures to be operated during flushing. Contractor shall 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 shall be responsible for any flood damage resulting from flushing of the system. Flushing shall 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, shall be flushed a minimum of 0.25 gallons per 24 hour period, ten times over a 14 day period.

#### 3.8.3.2 After Flushing

System shall be drained at low points. Strainer screens shall be removed, cleaned, and replaced. After flushing and cleaning, systems shall 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 shall be repaired by the Contractor. When the system flushing is complete, the hot-water system shall be adjusted for uniform circulation. Flushing devices and automatic control systems shall 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 shall not exceed limits established by 40 CFR 141.80 (c)(1). The water supply to the building shall be tested separately to ensure that any lead contamination found during potable water system testing is due to work being performed inside the building.

#### 3.8.4 Operational Test

Upon completion of flushing and prior to disinfection procedures, the Contractor shall subject the plumbing system to operating tests to demonstrate satisfactory installation, connections, adjustments, and functional and operational efficiency. Such operating tests shall cover a period of not less than 8 hours for each system and shall 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.
- i. Complete operation of each water pressure booster system, including pump start pressure and stop pressure.

#### 3.8.5 Disinfection

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

Water chlorination procedure shall be in accordance with AWWA C651 and AWWA C652 as modified and supplemented by this specification. The chlorinating material shall be hypochlorites or liquid chlorine. The chlorinating material shall 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.

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 shall 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.

Upon the specified verification, the system including tanks shall 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 shall be opened and closed several times.

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 shall be EPA approved for drinking water systems and shall comply with applicable local and state requirements.

Disinfection shall 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.

### 3.9 POSTED INSTRUCTIONS

Framed instructions under glass or in laminated plastic, including wiring and control diagrams showing the complete layout of the entire system, shall 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 shall be prepared in typed form, framed as specified above for the wiring and control diagrams and posted beside the diagrams. The framed instructions shall be posted before acceptance testing of the systems.

### 3.10 PERFORMANCE OF WATER HEATING EQUIPMENT

Standard rating condition terms are as follows:

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.

V = Rated volume in gallons

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

#### 3.10.1 Unfired Hot Water Storage

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

3.11 TABLES

TABLE I						
PIPE AND FITTING MATERIALS FOR DRAINAGE, WASTE, VENT AND CONDENSATE DRAIN PIPING SYSTEMS						
Item #	Pipe and Fitting Materials	SERVICE A	SERVICE B	SERVICE C	SERVICE D	SERVICE E
1	Cast iron soil pipe and fittings, hub and spigot, ASTM A74 with compression gaskets. Pipe and fittings shall be marked with the CISPI trademark.	X	X	X	X	
2	Cast iron soil pipe and fittings hubless, CISPI 301 and ASTM A888. Pipe and fittings shall 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	
5	Grooved pipe couplings, ferrous and non-ferrous pipe ASTM A536 And ASTM A47/A47M		X		X	
6	Ductile iron grooved joint fittings for ferrous pipe ASTM A536 and ASTM A47/A47M for use with Item 5		X		X	

TABLE I						
PIPE AND FITTING MATERIALS FOR DRAINAGE, WASTE, VENT AND CONDENSATE DRAIN PIPING SYSTEMS						
Item #	Pipe and Fitting Materials	SERVICE A	SERVICE B	SERVICE C	SERVICE D	SERVICE E
7	Bronze sand casting grooved joint pressure fittings for non-ferrous pipe ASTM B584, for use with Item 5		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			
9	Malleable-iron threaded fittings, galvanized ASME B16.3 for use with Item 10				X	
10	Steel pipe, seamless galvanized, ASTM A53/A53M, Type S, Grade B	X			X	
11	Seamless red brass pipe, ASTM B43				X	X
12	Bronzed flanged fittings, ASME B16.24 for use with Items 11 and 14				X	X
13	Cast copper alloy solder joint pressure fittings, ASME B16.18 for use with Item 14				X	X
14	Seamless copper pipe, ASTM B42					X

TABLE I						
PIPE AND FITTING MATERIALS FOR DRAINAGE, WASTE, VENT AND CONDENSATE DRAIN PIPING SYSTEMS						
Item #	Pipe and Fitting Materials	SERVICE A	SERVICE B	SERVICE C	SERVICE D	SERVICE E
15	Cast bronze threaded fittings, ASME B16.15				X	
16	Copper drainage tube, (DWV), ASTM B306	X*	X	X*	X	X
17	Wrought copper and wrought alloy solder-joint drainage fittings. ASME B16.29	X	X	X	X	X
18	Cast copper alloy solder joint drainage fittings, DWV, ASME B16.23	X	X	X	X	X
19	Acrylonitrile-Butadiene-Sty (ABS) plastic drain, waste, and vent pipe and fittings ASTM D2661, ASTM F628		X		X	
20	Polyvinyl Chloride plastic drain, waste and vent pipe and fittings, ASTM D2665, ASTM F891, (Sch 40) ASTM F1760		X		X	X
21	Process glass pipe and fittings, ASTM C1053					
22	High-silicon content cast iron pipe and fittings (hub and spigot, and mechanical joint), ASTM A518/A518M		X			

TABLE I						
PIPE AND FITTING MATERIALS FOR DRAINAGE, WASTE, VENT AND CONDENSATE DRAIN PIPING SYSTEMS						
Item #	Pipe and Fitting Materials	SERVICE A	SERVICE B	SERVICE C	SERVICE D	SERVICE E
23	Polypropylene (PP) waste pipe and fittings, ASTM D4101					
24	Filament-wound reinforced thermosetting resin (RTRP) pipe, ASTM D2996					
<p>SERVICE:</p> <p>A - Underground Building Soil, Waste and Storm Drain                      B - Aboveground Soil, Waste, Drain In Buildings                      C - Underground Vent                      D - Aboveground Vent                      E - Condensate Drain Aboveground</p> <p>* - Hard Temper</p>						

TABLE II				
PIPE AND FITTING MATERIALS FOR PRESSURE PIPING SYSTEMS				
Item #	Pipe and Fitting Materials	SERVICE A	SERVICE B	SERVICE C
1	Malleable-iron threaded fittings:			
	a. Galvanized, ASME B16.3 for use with Item 4a	X	X	X
	b. Same as "a" but not galvanized for use with Item 4b			
2	Grooved pipe couplings, ferrous pipe ASTM A536 and ASTM A47/A47M, non-ferrous pipe, ASTM A536 and ASTM A47/A47M	X	X	
3	Ductile iron grooved joint fittings for ferrous pipe ASTM A536 and ASTM A47/A47M, for use with Item 2	X	X	

TABLE II				
PIPE AND FITTING MATERIALS FOR PRESSURE PIPING SYSTEMS				
Item #	Pipe and Fitting Materials	SERVICE A	SERVICE B	SERVICE C
4	Steel pipe:			
	a. Seamless, galvanized, ASTM A53/A53M, Type S, Grade B	X	X	X
	b. Seamless, black, ASTM A53/A53M, Type S, Grade B			
5	Seamless red brass pipe, ASTM B43	X	X	X
6	Bronze flanged fittings, ASME B16.24 for use with Items 5 and 7	X	X	X
7	Seamless copper pipe, ASTM B42	X	X	X
8	Seamless copper water tube, ASTM B88, ASTM B88M	X**	X**	X***
9	Cast bronze threaded fittings, ASME B16.15 for use with Items 5 and 7	X	X	X
10	Wrought copper and bronze solder-joint pressure fittings, ASME B16.22 for use with Items 5, 7 and 8	X	X	X
11	Cast copper alloy solder-joint pressure fittings, ASME B16.18 for use with Item 8	X	X	X
12	Bronze and sand castings grooved joint pressure fittings for non-ferrous pipe ASTM B584, for use with Item 2	X	X	
13	Steel pipeline flanges, MSS SP-44			



TABLE II				
PIPE AND FITTING MATERIALS FOR PRESSURE PIPING SYSTEMS				
Item #	Pipe and Fitting Materials	SERVICE A	SERVICE B	SERVICE C
14	Fittings: brass or bronze; ASME B16.15, and ASME B16.18 ASTM B828	X	X	
15	Carbon steel pipe unions, socket-welding and threaded, MSS SP-83			
16	Malleable-iron threaded pipe unions ASME B16.39			
17	Nipples, pipe threaded ASTM A733			
18	Crosslinked Polyethylene (PEX) Plastic Pipe ASTM F877			
19	Press Fittings	X	X	
SERVICE: A - Cold Water Service Aboveground B - Hot Water Service 180 degrees F Maximum Aboveground C - Cold Water Service Belowground Indicated types are minimum wall thicknesses. ** - Type L - Hard *** - Type K - Hard temper with brazed joints only or type K-soft temper without joints in or under floors **** - In or under slab floors only brazed joints				

TABLE III				
STANDARD RATING CONDITIONS AND MINIMUM PERFORMANCE RATINGS FOR WATER HEATING EQUIPMENT				
<u>FUEL</u>	<u>STORAGE CAPACITY GALLONS</u>	<u>INPUT RATING</u>	<u>TEST PROCEDURE</u>	<u>REQUIRED PERFORMANCE</u>
A. Unfired Hot Water Storage, R-12.5 min.				
<p>TERMS:</p> <p>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.                      V = Rated storage volume in gallons                      Q = Nameplate input rate in Btu/h</p>				

-- End of Section --



SECTION 23 00 00

AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEMS  
08/10

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  |
| AMCA 210 | (2016) Laboratory Methods of Testing Fans for Aerodynamic Performance Rating |
| AMCA 300 | (2014) Reverberant Room Method for Sound Testing of Fans                     |
| AMCA 301 | (2014) Methods for Calculating Fan Sound Ratings from Laboratory Test Data   |

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                 |
| AHRI 430         | (2009) Central-Station Air-Handling Units  |
| 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 11 | (2014) Load Ratings and Fatigue Life for Roller Bearings |
| ABMA 9  | (2015) Load Ratings and Fatigue Life for Ball Bearings   |

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

- |             |   |
|-------------|---|
| ASHRAE 52.2 | (2017) Method of Testing General Ventilation Air-Cleaning Devices for |
|-------------|---|

Removal Efficiency by Particle Size

ASHRAE 62.1 (2022) Ventilation for Acceptable Indoor Air Quality

ASHRAE 70 (2023) Method of Testing the Performance of Air Outlets and Inlets

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME A13.1 (2023) Scheme for the Identification of Piping Systems

ASTM INTERNATIONAL (ASTM)

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

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 C1071 (2019) Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)

ASTM C553 (2013; R 2019) Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications

ASTM D1654 (2008; R 2016; E 2017) Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments

ASTM D3359 (2017) Standard Test Methods for Rating Adhesion by Tape Test

ASTM D520 (2000; R 2011) Zinc Dust Pigment

ASTM E2016 (2022) Standard Specification for Industrial Woven Wire Cloth

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 701 (2023; ERTA 1 2023) Standard Methods of Fire Tests for Flame Propagation of Textiles and Films

NFPA 90A (2021) Standard for the Installation of Air Conditioning and Ventilating Systems

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 1884 (2003) Fibrous Glass Duct Construction Standards, 7th Edition

SMACNA 1966 (2020) HVAC Duct Construction Standards Metal and Flexible, 4th Edition

U.S. DEPARTMENT OF ENERGY (DOE)

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

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

40 CFR 82 Protection of Stratospheric Ozone

PL 109-58 Energy Policy Act of 2005 (EPAct05)

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

UL 555S (2014; Reprint Oct 2020) UL Standard for Safety Smoke Dampers

UL 586 (2009; Reprint Sep 2022) UL Standard for Safety High-Efficiency Particulate, Air Filter Units

UL 6 (2022) UL Standard for Safety Electrical

Rigid Metal Conduit-Steel

UL 705	(2017; Reprint Aug 2022) UL Standard for Safety Power Ventilators
UL 900	(2015; Reprint Aug 2022) UL Standard for SafetyStandard for Air Filter Units
UL Bld Mat Dir	(updated continuously online) Building Materials Directory
UL Electrical Constructn	(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 shall 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. Labels shall be in accordance with the typical examples below:

SERVICE	LABEL AND TAG DESIGNATION
Air handling unit Number	AHU - 01
Control and instrument air	CONTROL AND INSTR.
Exhaust Fan Number	EF - 01
VAV Box Number	VAV - 01
Fan Coil Unit Number	FCU - 01
Unit Heater	UH-01
Computer Room Air-Conditioning Unit Number	CRAC - 01

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 shall 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 shall be in accordance with ASME A13.1 .

### 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 Notebook, 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

Insulated Nonmetallic Flexible Duct Runouts; G

Duct Connectors; G

Duct Access Doors; G

Fire Dampers; G

Manual Balancing Dampers; G

Sound Attenuation Equipment; G

Diffusers; G

Registers; G

Louvers; G

Air Vents, Penthouses, Goosenecks, and Gravity Hoods; G

Centrifugal Fans; G

In-Line Centrifugal Fans; G

Propeller Type Power Wall Ventilators; G

Computer Room Air Conditioning Units; G

Room Fan-Coil Units; G

Variable Volume, Single Duct Terminal Units; G

Test Procedures; G

Diagrams; G

Packaged Resistive Element Humidifier; G

SD-06 Test Reports

Performance Tests; G

Damper Acceptance Test; G

SD-07 Certificates

BoltsOzone Depleting SubstancesTechnical 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

Automatic Smoke-Fire Dampers; G

Centrifugal Fans; G

In-Line Centrifugal Fans; G

Propeller Type Power Wall Ventilators; G

Air Handler Units; G

Room Fan-Coil Units; G

Variable Volume, Single Duct Terminal Units; G

SD-11 Closeout Submittals

Energy Efficient Equipment; S

Reduce Volatile Organic Compounds (VOC); S

Indoor Air Quality During Construction; S

Ozone Depleting Substances for Refrigerants; 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 certified product categories, equipment selected shall have as a minimum the efficiency rating identified under "Energy-Efficient Products" at <http://www1.eere.energy.gov/femp/procurement>.

These specifications conform to the efficiency requirements as defined in Public Law PL 109-58, "Energy Policy Act of 2005" for federal procurement of energy-efficient products. Equipment having a lower efficiency than Energy Star or FEMP requirements may be specified if the designer determines the equipment to be more life-cycle cost effective using the life-cycle cost analysis methodology and procedure in 10 CFR 436.

#### 1.4.1 Asbestos Prohibition

Do not use asbestos and asbestos-containing products.

#### 1.4.2 Ozone Depleting Substances Used as Refrigerants

Minimize releases of Ozone Depleting Substances (ODS) during repair, maintenance, servicing or disposal of appliances containing ODS's by complying with all applicable sections of 40 CFR 82 Part 82 Subpart F. Any person conducting repair, maintenance, servicing or disposal of equipment containing refrigerants must comply with the following:

- a. Do not knowingly vent or otherwise release into the environment, Class I or Class II substances used as a refrigerant.
- b. Do not open appliances without meeting the requirements of 40 CFR 82 Part 82.156 Subpart F, regarding required practices for evacuation and collection of refrigerant, and 40 CFR 82 Part 82.158 Subpart F, regarding standards of recycling and recovery equipment.
- c. Only persons who comply with 40 CFR 82 Part 82.161 Subpart F, regarding technician certification, can conduct work on appliances containing refrigerant.

In addition, provide copies of all applicable certifications to the Contracting Officer at least 14 calendar days prior to initiating maintenance, repair, servicing, dismantling or disposal of appliances, including:

- a. Proof of Technician Certification
- b. Proof of Equipment Certification for recovery or recycling equipment.
- c. Proof of availability of certified recovery or recycling equipment.

#### 1.4.3 Use of Ozone Depleting Substances, Other than Refrigerants

The use of Class I or Class II ODS's listed as nonessential in 40 CFR 82 Part 82.66 Subpart C is prohibited. These prohibited materials and uses include:

- a. Any plastic party spray streamer or noise horn which is propelled by a chlorofluorocarbon
- b. Any cleaning fluid for electronic and photographic equipment which contains a chlorofluorocarbon; including liquid packaging, solvent wipes, solvent sprays, and gas sprays.
- c. Any plastic flexible or packaging foam product which is manufactured with or contains a chlorofluorocarbon, including, open cell foam, open cell rigid polyurethane poured foam, closed cell extruded polystyrene sheet foam, closed cell polyethylene foam and closed cell polypropylene foam except for flexible or packaging foam used in coaxial cabling.
- d. Any aerosol product or other pressurized dispenser which contains a chlorofluorocarbon, except for those listed in 40 CFR 82 Part 82.66 Subpart C.

Request a waiver if a facility requirement dictates that a prohibited material is necessary to achieve project goals. Submit the waiver request in writing to the Contracting Officer. The waiver will be evaluated and dispositioned.

#### 1.4.4 Detail Drawings

Submit detail drawings showing equipment layout, including assembly and installation details and electrical connection diagrams; metal and FRP 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

Submit proposed test procedures and test schedules for the ductwork leak test, and performance tests of systems, at least 2 weeks prior to the start of related testing.

#### 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 PRODUCT SUSTAINABILITY CRITERIA

For products in this section, where applicable and to extent allowed by performance criteria, provide and document the following:

#### 2.1.1 Energy Efficient Equipment

Provide documentation in conformance with Section 01 33 29 SUSTAINABILITY REPORTING paragraph ENERGY EFFICIENT EQUIPMENT that the following products meet energy efficiency requirements as outlined in this section:

- a. Centrifugal Fans
- b. In-Line Centrifugal Fans
- c. Propeller Type Power Wall Ventilators
- d. Computer Room Air Conditioning Units
- e. Air Handling Units
- f. Room Fan-Coil Units

#### 2.1.2 Reduce Volatile Organic Compounds (VOC) for sealants, coatings or adhesives

Low or no VOC's and no added urea formaldehyde for duct sealants, coatings or adhesives, in conformance with Section 01 33 29 SUSTAINABILITY REPORTING paragraph REDUCE VOLATILE ORGANIC COMPOUNDS (VOC).

#### 2.1.3 Ozone Depleting Substances for Refrigerants

Do not use any Ozone Depleting Substances (ODS) as Refrigerants per requirements in 01 33 29 SUSTAINABILITY REPORTING paragraph OZONE DEPLETING SUBSTANCES.

### 2.2 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.

### 2.3 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. Identification plates shall be three layers, black-white-black, engraved to show white letters on black background. Letters shall be upper case. Identification plates 1-1/2-inches high and smaller shall be 1/16-inch thick, with engraved lettering 1/8-inch high; identification plates larger than 1-1/2-inches high shall be 1/8-inch thick, with engraved lettering of

suitable height. Identification plates 1-1/2-inches high and larger shall have beveled edges. Install identification plates using a compatible adhesive.

#### 2.4 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 05 50 13 MISCELLANEOUS METAL FABRICATIONS.

#### 2.5 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. Integral size motors shall be the premium efficiency type 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. All multi-speed motors shall be ECM type motors or inverter-duty motors with variable frequency drives. Provide variable frequency drives for motors as specified in Section 26 29 23 VARIABLE FREQUENCY DRIVE SYSTEMS UNDER 600 VOLTS.

## 2.6 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 shall not degrade the surrounding concrete.

## 2.7 SEISMIC PROTECTION AND VIBRATION CONTROLS

Provide seismic protection in accordance with the requirements of Section 23 05 48.19 SEISMIC BRACING FOR HVAC. Provide vibration controls in accordance with the requirements of Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT.

## 2.8 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.

## 2.9 INDOOR AIR QUALITY

Provide equipment and components that comply with the requirements of ASHRAE 62.1 unless more stringent requirements are specified herein.

## 2.10 DUCT SYSTEMS

### 2.10.1 Metal Ductwork

Provide metal ductwork construction, including all fittings and components, that complies with SMACNA 1966, as supplemented and modified by this specification .

- a. Duct work shall be constructed meeting the requirements for the duct system static pressure specified in APPENDIX D of Section 23 05 93 TESTING, ADJUSTING AND BALANCING FOR HVAC. All metal ductwork shall be galvanized sheet steel with a galvanized coating designation of G90 unless otherwise indicated. Galvanized metal ductwork exposed to view shall have a mill phosphatized finish.
- 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. All ductwork shall be Seal Class "A".
- d. 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.
- e. 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. Fabricate outdoor air intake ducts and plenums with watertight soldered or brazed joints and seams.

#### 2.10.1.1 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.

#### 2.10.1.2 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.

#### 2.10.1.3 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.

#### 2.10.2 Duct Access Doors

Provide hinged access doors conforming to SMACNA 1966 in ductwork and plenums where indicated and at all air flow sensors, automatic dampers, fire dampers, duct smoke detectors, 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.

#### 2.10.3 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 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 parallel multi-blade fire dampers with blades in the airstream. 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.

#### 2.10.4 Manual Balancing Dampers

- a. 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.
- b. 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 access doors or panels in hard ceiling, partitions and walls for access to all concealed damper operators and damper locking setscrews. Coordinate location of doors or panels with other affected contractors.
- c. 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. Stand-off mounting items shall be integral with the operator or standard accessory of the damper manufacturer.
- d. All manual balancing dampers connected to outside air for make-up air, exhaust air or relief air and ventilation shall be Class 1A construction.

##### 2.10.4.1 Square or Rectangular Dampers

###### 2.10.4.1.1 Duct Height 12 inches and Less

###### 2.10.4.1.1.1 Frames

Width	Height	Galvanized Steel Thickness	Length
Maximum 19 inches	Maximum 12 inches	Minimum 20 gauge	Minimum 3 inches
More than 19 inches	Maximum 12 inches	Minimum 16 gauge	Minimum 3 inches

2.10.4.1.1.2 Single Leaf Blades

Width	Height	Galvanized Steel Thickness	Length
Maximum 19 inches	Maximum 12 inches	Minimum 20 gauge	Minimum 3 inches
More than 19 inches	Maximum 12 inches	Minimum 16 gauge	Minimum 3 inches

2.10.4.1.1.3 Blade Axles

To support the blades of round dampers, provide galvanized steel shafts supporting the blade the entire duct diameter frame-to-frame. Axle shafts shall extend through standoff bracket and hand quadrant.

Width	Height	Material	Square Shaft
Maximum 19 inches	Maximum 12 inches	Galvanized Steel	Minimum 3/8 inch
More than 19 inches	Maximum 12 inches	Galvanized Steel	Minimum 1/2 inch

2.10.4.1.1.4 Axle Bearings

Support the shaft on each end at the frames with shaft bearings. Shaft bearings configuration shall be a pressed fit to provide a tight joint between blade shaft and damper frame.

Width	Height	Material
Maximum 19 inches	Maximum 12 inches	solid nylon, or equivalent solid plastic, or oil-impregnated bronze
More than 19 inches	Maximum 12 inches	oil-impregnated bronze

2.10.4.1.1.5 Control Shaft/Hand Quadrant

Provide dampers with accessible locking-type control shaft/hand quadrant operators.

Provide stand-off mounting brackets, bases, or adapters for the locking-type quadrant operators on dampers installed on ducts to be thermally insulated. Stand-off distance shall be a minimum of 2 inches off the metal duct surface. Stand-off mounting items shall be integral with the operator or standard accessory of the damper manufacturer.

2.10.4.1.1.6 Finish

Mill Galvanized

2.10.4.2 Round Dampers

2.10.4.2.1 Frames

Size	Galvanized Steel Thickness	Length
4 to 20 inches	Minimum 20 gauge	Minimum 6 inches
22 to 30 inches	Minimum 20 gauge	Minimum 10 inches
32 to 40 inches	Minimum 16 gauge	Minimum 10 inches

2.10.4.2.2 Blades

Size	Galvanized Steel Thickness
4 to 20 inches	Minimum 20 gauge
22 to 30 inches	Minimum 16 gauge
32 to 40 inches	Minimum 10 gauge

2.10.4.2.3 Blade Axles

To support the blades of round dampers, provide galvanized steel shafts supporting the blade the entire duct diameter frame-to-frame. Axle shafts shall extend through standoff bracket and hand quadrant.

Size	Shaft Size and Shape
4 to 20 inches	Minimum 3/8 inch square
22 to 30 inches	Minimum 1/2 inch square
32 to 40 inches	Minimum 3/4 inch square

2.10.4.2.4 Axle Bearings

Support the shaft on each end at the frames with shaft bearings constructed of oil-impregnated bronze, or solid nylon, or a solid plastic equivalent to nylon. Shaft bearings configuration shall be a pressed fit to provide a tight joint between blade shaft and damper frame.

Size	Material
4 to 20 inches	solid nylon, or equivalent solid plastic, or oil-impregnated bronze
22 to 30 inches	solid nylon, or equivalent solid plastic, or oil-impregnated bronze
32 to 40 inches	oil-impregnated bronze, or stainless steel sleeve bearing

2.10.4.2.5 Control Shaft/Hand Quadrant

Provide dampers with accessible locking-type control shaft/hand quadrant

operators.

Provide stand-off mounting brackets, bases, or adapters for the locking-type quadrant operators on dampers installed on ducts to be thermally insulated. Stand-off distance shall be a minimum of 2 inches off the metal duct surface. Stand-off mounting items shall be integral with the operator or standard accessory of the damper manufacturer.

Finish

Mill Galvanized

#### 2.10.5 Automatic Balancing Dampers

Provide dampers as specified in paragraph SUPPLEMENTAL COMPONENTS/SERVICES, subparagraph CONTROLS. All automatic balancing and control dampers connected to outside air for make-up air exhaust air or relief air and ventilation shall be Class 1A construction.

#### 2.10.6 Automatic Smoke-Fire Dampers

Multiple blade type, 180 degrees F fusible fire damper link; smoke damper assembly to include electric damper operator. UL 555 as a 1.5 hour rated fire damper; further qualified under UL 555S as a leakage rated damper. Provide a leakage rating under UL 555S that is no higher than Class III at an elevated temperature Category B (250 degrees F for 30 minutes). Ensure that pressure drop in the damper open position does not exceed 0.1 inch water gauge with average duct velocities of 2500 fpm.

#### 2.10.7 Sound Attenuation Equipment

##### 2.10.7.1 Duct Silencers

Provide duct silencers as indicated. Provide factory fabricated duct silencers, tested by an independent laboratory for sound and performance characteristics. Provide a net sound reduction as indicated. Maximum permissible pressure drop shall be as indicated on the drawings. Construct silencers 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 3,000 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, 4 inch thick acoustical blanket insulation with airstream surface protected by an acrylic coating with flexible glass mat reinforcement, 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.

#### 2.10.8 Diffusers, Registers, and Grilles

Provide factory-fabricated units of steel or aluminum as scheduled on the drawings 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.

##### 2.10.8.1 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 Constructn 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.

##### 2.10.8.2 Registers

Double-deflection supply registers. Provide manufacturer-furnished volume dampers where indicated on the drawings. Provide volume dampers of the group-operated, opposed-blade type and key adjustable by inserting key through face of register. Operating mechanism shall not project through any part of the register face. Automatic volume control devices and acceptable. Provide exhaust and return registers as specified for supply registers, except provide exhaust and return registers that have a single set of nondirectional face bars or vanes having the same appearance as the supply registers.

##### 2.10.9 Louvers

Provide louvers for installation in exterior walls that are associated with the air supply and distribution system as specified in Section

08 91 00 METAL WALL LOUVERS.

#### 2.10.10 Air Vents, Penthouses, Goosenecks, and Gravity Hoods

Fabricate air vents, penthouses, goosenecks, and gravity hoods from galvanized steel or aluminum sheets with galvanized or aluminum structural shapes as indicated on the drawings.. 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, goosenecks, and gravity hoods with bird screen.

#### 2.10.11 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.

### 2.11 AIR SYSTEMS EQUIPMENT

#### 2.11.1 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 shall not exceed 88 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 120 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 specified in Section 23 05 48.00 40, VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT and scheduled on the drawings. 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. Provide motor starters and variable frequency drives as indicated on the drawings in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and Section 26 29 23 VARIABLE FREQUENCY DRIVE SYSTEMS UNDER 600 VOLTS.

#### 2.11.1.1 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. Unless otherwise indicated on the drawings or specified herein, 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. Unless otherwise indicated, provide motors that do not exceed 1800 rpm and have open dripproof enclosures.

#### 2.11.1.2 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 open dripproof, totally enclosed, or explosion-proof enclosure as indicated on the drawings.

#### 2.11.1.3 Propeller 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, totally enclosed fan cooled type motor.

#### 2.11.1.4 Tube Axial Direct Drive Inline Fan

Provide tube axial direct drive inline type fans with cast aluminum airfoil propellers and welded steel housings with integral punched inlet and outlet flanges. Propellers shall be dynamically balanced and locked to the motor shaft with a tapered bushing. Hubs shall be two piece aluminum coatings or equal that lock blades in place. Fans shall be coated with the manufacturer's standard protective coating with a minimum dry film thickness of not less than 2 mils.

## 2.11.2 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. All cooling coil casings, frames and drip pans shall be constructed of stainless steel. Provide casing and tube support sheets that are not lighter than 16 gauge stainless steel, formed to provide structural strength. When required, provide multiple tube supports to prevent tube sag. Test each coil at the factory under water at not less than 400 psi air pressure and make suitable for 200 psi working pressure and 300 degrees F operating temperature unless otherwise stated. Mount coils for counterflow service. Rate and certify coils to meet the requirements of AHRI 410.

### 2.11.2.1 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 chilled water coils with stainless steel drain pans and removable heating water coils with galvanized steel drain pans.

### 2.11.2.2 Eliminators

Equip each cooling coil having an air velocity of over 400 fpm through the net face area with moisture eliminators, unless the coil manufacturer guarantees, over the signature of a responsible company official, that no moisture can be carried beyond the drip pans under actual conditions of operation. Construct of minimum 24 gage stainless steel, removable through the nearest access door in the casing or ductwork. Provide eliminators that have not less than two bends at 45 degrees and are spaces not more than 2-1/2 inches center-to-center on face. Provide each bend with an integrally formed hook as indicated in the SMACNA 1884.

## 2.11.3 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.

### 2.11.3.1 Extended Surface Pleated Panel Filters

Provide 2 inch or 4 inch depth as indicated, sectional, disposable type filters of the size indicated with a MERV of 8 or 13 as indicated 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.

### 2.11.3.2 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.



### 2.11.3.3 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 handler units. Gauges shall be at least 3-7/8 inches in diameter, with white dials with black figures, and graduated in 0.01 inch of water, 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 taps with integral compression fittings, two molded plastic vent valves, two 5 foot minimum lengths of 1/4 inch diameter vinyl tubing, and all hardware and accessories for gauge mounting.

## 2.12 PACKAGED RESISTIVE ELEMENT HUMIDIFIER

### 2.12.1 General

Provide packaged resistive element steam generating humidifier and short absorption steam dispersion panel complete with interconnecting steam and condensate piping and associated accessories for a complete operational system.

### 2.12.2 Packaged Resistive Element Humidifier

Packaged humidifier shall have a powder coated or equal steel enclosure designed for wall or structural support mounting. Resistive element technology shall include incoloy based resistive heating elements for steam production. Unit shall be suitable for use with potable water and shall produce mineral free, odorless, sterile steam at atmospheric pressure in a stainless steel cylinder. Unit shall be configured with a removable base mounted scale tank that collects scale deposits and is removable for disposal of scale. The reservoir shall be configured for scale control with a double wall design that permits cold water to pass around the outer section of the boiling chamber. Other designs that can be shown with documented data to provide reservoir scale removable equivalent to the double wall / cold water method will be acceptable. A magnetic electronic float system located outside of the boiling water shall provide reservoir water level control. Drainage system shall be automatic and shall include drain water tempering system to limit drain water temperature to 140 degrees F.

### 2.12.3 Packaged Resistive Element Humidifier Controls

Packaged humidifier shall be provided with a microprocessor based touch screen controller with intuitive color use HMI. Controller shall provide monitoring and programmable control of the steam generation process and drain control. Controller shall be provided with self-test diagnostics on start-up. Controller shall be configured to provide seamless communications with the facility Direct Digital Control System.

### 2.12.4 Integral Blower Pack

Provide integral blower pack fully factory assembled with internal power supply, steam and condensate connections. Blower pack shall create an air stream to allow absorption of the atmospheric steam in the conditioned environment. Blower packs shall have two fan speed settings. The high speed setting shall provide shorter absorption distances while the low speed shall provide quieter operation with longer absorption distance.

## 2.13 AIR HANDLER UNITS

### 2.13.1 Factory-Fabricated Air Handler Units

Provide single-zone draw-through type units as indicated. Units shall include fans, coils, airtight insulated casing, prefilters, access sections where indicated, mixing box, final filters, and appurtenances required for specified operation. Provide vibration isolators meeting the requirements of section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT and as indicated on the drawings. Physical dimensions of each air handler unit shall be suitable to fit space allotted to the unit with the capacity indicated. Provide air handler unit that is rated in accordance with AHRI 430 and AHRI certified for cooling.

#### 2.13.1.1 Casings

Provide the following:

- a. Casing sections shall be minimum 3 inch double wall insulated type with outer wall (entire unit: walls, roof and floors), constructed of a minimum 16 gauge galvanized steel. Inner casing (entire unit: walls, roof and floors) of double-wall units shall be minimum 20 gauge solid galvanized steel except the inner casing of cooling coil sections which shall be 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. All internal structural components of cooling coil sections shall be corrosion-resisting sheet steel conforming the ASTM A167, Type 304. All air handler unit structural elements shall be welded construction.
- b. Individually removable exterior panels with standard tools. Removal shall not affect the structural integrity of the unit. Furnish casings with access sections, according to paragraph AIR HANDLER 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 16 gauge outer and 20 gauge inner panels made of either galvanized steel or corrosion-resisting sheet steel conforming to ASTM A167, Type 304. Doors shall be rigid and provided with heavy duty hinges and latches. Inspection doors shall be a minimum 12 inches wide by 12 inches high. Access doors shall 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 and 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 shall 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. Coils shall be individually removable from the casing. Provide all Air Handler Unit heating coils with double wall insulated type drain pans equal to those specified for cooling coils except pan material shall be 16 gauge galvanized steel.

- e. Casing insulation that conforms to NFPA 90A. Double-wall casing sections (entire unit: walls, roof and floors) shall be insulated with not less than 3 inch thick, 3 pound density coated fibrous glass material having a thermal conductivity not greater than 0.23 Btu/hr-sf-F. Foil-faced insulation is not an acceptable substitute for use with double wall casing. Double wall insulation shall be completely sealed by inner and outer panels.
- f. 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.

#### 2.13.1.2 Heating and Cooling Coils

Provide coils as specified in paragraph AIR SYSTEMS EQUIPMENT.

#### 2.13.1.3 Air Filters

Provide air filters as specified in paragraph AIR SYSTEMS EQUIPMENT for types and thickness indicated.

#### 2.13.1.4 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. Bearings shall be 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. Motor sheaves that are variable pitch for 25 hp and below and fixed pitch above 25 hp as defined by AHRI Guideline 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 open dripproof enclosures.
- e. Factory installed variable frequency drives shall conform to the applicable requirements of Section 26 29 23 ADJUSTABLE SPEED DRIVE (ASD) SYSTEMS UNDER 600 VOLTS.

#### 2.13.1.5 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.

#### 2.13.1.6 Factory Painting

Factory paint Air Handler Unit in accordance with paragraph FACTORY PAINTING. Factory paint color shall be manufacturer's standard gray. Submit air handler units factory paint color samples for Government review.

### 2.14 TERMINAL UNITS

#### 2.14.1 Variable Air Volume (VAV) 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.
- 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.

##### 2.14.1.1 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.

## 2.15 FACTORY PAINTING

Factory paint new equipment, which are not of galvanized construction except where specific galvanized construction Air Handler Units are specified to be factory painted. 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.

Factory painting that has been damaged prior to acceptance by the Contracting Officer shall be field painted in compliance with the requirements of paragraph FIELD PAINTING OF MECHANICAL EQUIPMENT.

## 2.16 SUPPLEMENTAL COMPONENTS/SERVICES

### 2.16.1 Chilled Water Piping

The requirements for chilled water piping and accessories are specified in Section 23 64 26 CHILLED WATER PIPING SYSTEMS

### 2.16.2 Water Heating System Accessories

The requirements for water heating accessories such as expansion tanks are specified in Section 23 52 00 HEATING BOILERS.

### 2.16.3 Condensate Drain Lines

Provide and install condensate drainage for each item of equipment that generates condensate in accordance with Section 23 64 26 CHILLED WATER PIPING SYSTEMS except as modified herein.

### 2.16.4 Backflow Preventers

The requirements for backflow preventers are specified in Section 22 00 00 PLUMBING, GENERAL PURPOSE.

### 2.16.5 Insulation

The requirements for shop and field applied insulation are specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

### 2.16.6 Controls

The requirements for controls are specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and as indicated for Contractor furnished, unit manufacturer installed variable air volume terminal units..

### PART 3 EXECUTION

#### 3.1 CONSTRUCTION-RELATED SUSTAINABILITY CRITERIA

Perform and document Indoor Air Quality During Construction. Provide documentation showing that after construction ends, and prior to occupancy, new filters were installed in conformance with Section 01 33 29 SUSTAINABILITY REPORTING paragraph INDOOR AIR QUALITY DURING CONSTRUCTION.

#### 3.2 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.

#### 3.3 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.

##### 3.3.1 Condensate Drain Lines

Provide water seals in the condensate drain from all units. Provide a depth of each seal as indicated on the drawings. 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.

##### 3.3.2 Equipment and Installation

Provide frames and supports for tanks, compressors, pumps, valves, air handler units, fans, coils, dampers, and other similar items requiring supports. Floor mount or ceiling hang air handler 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.

### 3.3.3 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 05 50 13 MISCELLANEOUS METAL FABRICATIONS.

### 3.3.4 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.

### 3.3.5 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.

### 3.3.6 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.

### 3.3.7 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 mixes with the return air stream.

### 3.3.8 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.

### 3.3.9 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.

### 3.3.10 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.

### 3.4 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 28 calendar days before being loaded.

### 3.5 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.

### 3.6 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.

### 3.7 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.

#### 3.7.1 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.

### 3.7.2 Framed Prepared Openings

Fabricate framed prepared openings from 20 gauge galvanized steel, unless otherwise indicated.

### 3.7.3 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.

### 3.7.4 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.

### 3.7.5 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. Firestopping materials be furnished and installed by the Firestopping installer and shall conform to the requirements in Section 07 84 00 FIRESTOPPING.

## 3.8 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.

### 3.8.1 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.

### 3.8.2 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.

### 3.8.3 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.

## 3.9 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.

## 3.10 DUCTWORK LEAK TESTS

The requirements for ductwork leak tests are specified in Section 23 05 93 TESTING, ADJUSTING AND BALANCING FOR HVAC.

## 3.11 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.

## 3.12 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.

## 3.13 PERFORMANCE TESTS

After testing, adjusting, and balancing is complete as specified, test each system as a whole to see that all items perform as integral parts of the system and temperatures and conditions are evenly controlled throughout the building. Record the testing during the applicable season. Make corrections and adjustments as necessary to produce the conditions indicated or specified. Conduct capacity tests and general operating tests by an experienced engineer. Provide tests that cover a period of not less than 1 days for each system and demonstrate that the entire system is functioning according to the specifications. Make

coincidental chart recordings at points indicated on the drawings for the duration of the time period and record the temperature at space thermostats or space sensors, the humidity at space humidistats or space sensors and the ambient temperature and humidity in a shaded and weather protected area.

Submit test reports for the performance tests in booklet form, upon completion of testing. Document phases of tests performed including initial test summary, repairs/adjustments made, and final test results in the reports.

### 3.14 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 install 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. 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.

### 3.15 OPERATION AND MAINTENANCE

#### 3.15.1 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

#### 3.15.2 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 16 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 05 48.00 40

VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT  
08/15

PART 1 GENERAL

Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEMS applies to work specified in this section to the extent applicable.

Section 23 52 00 HEATING BOILERS applies to work specified in the section to the extent applicable.

Section 23 64 26 CHILLED WATER PIPING SYSTEMS applies to work specified in this section to the extent applicable.

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 S2.71 (1983; R 2006) Guide to the Evaluation of Human Exposure to Vibration in Buildings

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

ASHRAE HVAC APP IP HDBK (2016) HVAC Applications Handbook, I-P Edition

NATIONAL ENVIRONMENTAL BALANCING BUREAU (NEBB)

NEBB PROCEDURAL STANDARDS (2005) Procedural Standards for TAB (Testing, Adjusting and Balancing) Environmental Systems

1.2 ADMINISTRATIVE REQUIREMENTS

Submit equipment and performance data for vibration isolator systems as specified herein and indicated on the drawings including, where applicable, equipment base design; inertia-block mass relative to support equipment weight; spring loads and free, operating, and solid heights of spring; spring diameters; nonmetallic isolator loading and deflection; disturbing frequency; natural frequency of mounts; deflection of working member; and anticipated amount of physical movement at the reference points.

Ensure the data includes information on the following where applicable:

- a. Mountings
- b. Bases
- c. Isolators

- d. Floor-Mounted Piping
- e. Vertical Piping

Prior to commencement of installation, submit installation drawings for vibration isolator systems including equipment and performance requirements.

Indicate within outline drawings for vibration isolator systems, overall physical features, dimensions, ratings, service requirements, and weights of equipment.

### 1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. Submittals with an "S" are for inclusion in the Sustainability Notebook, 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

Installation Drawings; G

Outline Drawings; G

#### SD-03 Product Data

Equipment and Performance Data; G

Isolators; G

#### SD-06 Test Reports

Type of Isolator; G

Type of Base; G

Allowable Deflection; G

Measured Deflection; G

### 1.4 QUALITY CONTROL

Ensure all vibration-control apparatus is the product of a single manufacturing source, where possible. Human exposure levels should be considered using ASA S2.71 and NEBB PROCEDURAL STANDARDS.

## PART 2 PRODUCTS

### 2.1 SYSTEM DESCRIPTION

Scheduled isolation mounting is in inches and is a minimum static deflection.

Determine exact mounting sizes and number of isolators by the isolator manufacturer based on equipment that will be installed and equipment location. Check equipment revolutions per minute (rpm) and spring

deflections to verify that resonance cannot occur.

#### 2.1.1.1 Design Requirements

Design for vibration isolation using ASHRAE HVAC APP IP HDBK, Chapter 48, as applicable to the following sections. All isolator types may not be required.

##### 2.1.1.1.1 Mountings

Provide the following mountings as applicable and indicated on the drawings:

Type A: Composite pad, with 0.25-inch thick elastomer top and bottom layers, molded to contain a pattern with nonslip characteristics in all horizontal directions. Elastomer loading is not to exceed 40 pounds per square inch (psi). Ensure minimum overall thickness is 1 inch. Maximum deflections up to 0.25-inch are allowed.

Type B: Double elastomer-in-shear with molded-in steel reinforcement in top and bottom. Maximum deflections up to 0.50-inch are allowed.

Type C: Free-standing laterally stable open-spring type for deflections over 0.50-inch, with built-in bearing and leveling provisions, 0.25-inch thick Type A base elastomer pads, and accessories. Ensure outside diameter of each spring is equal to or greater than 0.9 times the operating height of the spring under rated load.

Type D: Partially housed type, containing one or more vertically restrained springs with at least 0.50-inch clearance maintained around springs, with adjustable limit stops, 0.25-inch thick Type A base elastomer pads, and accessories.

Type E: Pendulum-suspension configuration with free-standing stable spring with resilient horizontal and vertical restraints to allow maximum movements of 0.25-inch in each direction, 0.25-inch thick Type A base elastomer pads.

Type F: Combination spring and elastomer-in-shear steel or elastomer-in-shear as indicated on the drawings, framed for hanger-rod mounting, with minimum total static deflection of 1-inch for combination spring and elastomer-in-shear and 0.4 inch for elastomer-in-shear.

##### 2.1.1.1.2 Bases

Provide the following bases:

Type U: Unit isolators without rails, structural-steel bases, or inertia blocks.

Type R: Rails, connected mill-rolled structural steel, of sufficient dimension to preclude deflection at midpoint of unsupported span in excess of 1/1,440th of the span between isolators, power transmission, component misalignment, and any overhung weight. Where Type R bases are specified and the equipment proposed requires additional base support, use a Type S base.

Type S: Structural-steel bases common to a supported assembly, made

from welded-joint mill-rolled structural steel with closed-perimeter configuration, isolators attached to outrigger supports.

Ensure height of steel members is sufficient to provide stiffness required to maintain equipment manufacturer's recommended alignment and duty efficiency of power-transmission components. Ensure height of steel member does not result in member deflection at midpoint of unsupported span of more than 1/1,440th of the span between isolators. Minimum height is 5-inches.

Type CIB: Provide concrete inertia blocks common to the entire assembly, with welded-joint construction, mill-rolled structural-steel perimeters, welded-in No. 4 reinforcing bars 8-inches on center each way near the bottom of the block, outrigger-isolator mounting provisions, anchor bolts. Fill with 3,000 psi cured-strength concrete.

Configure rectangular inertia bases to accommodate equipment supported.

Ensure minimum thickness of inertia base, in addition to providing suitable mass, is sufficient to provide stiffness to maintain equipment manufacturer's recommended alignment and duty efficiency of power-transmission components, and is sufficient to result in base deflection at midpoint of unsupported span of not more than 1/1,440th of the span between isolators. Verify minimum thickness, the preceding requirements notwithstanding, is 8 percent of the longest base dimension.

Ensure pumps with flexible couplings do not have inertia base less than 8-inches thick, and the minimum mass of concrete inertia block is equal in weight to supported equipment.

#### 2.1.1.3 Pipe And Duct Vibration Isolation

Type G: Provide isolators with in-series contained steel springs and preformed fibrous-glass or chloroprene-elastomer elements for connecting to building-structure attachments. Load devices by supported system during operating conditions to produce a minimum spring and elastomer static deflection of 1-inch and 3/8-inch, respectively.

Type H: Provide isolators with contained chloroprene-elastomer elements for connecting to building-structure attachments. Load devices by supported system during operating conditions to produce a minimum elastomer static deflection of 3/8-inch.

Type J: Provide isolators with elastomers mounted on floor-supported columns or directly on the floor. Load devices by supported system during operating conditions to produce a minimum elastomer static deflection of 3/8-inch.

#### 2.1.1.4 Floor-Mounted Piping

Type K: Provide isolators with springs mounted on floor-supported columns or directly on the floor. Load devices by supported system during operating conditions to produce a minimum spring static deflection of 1-inch.

#### 2.1.1.5 Vertical Piping

Type L: Provide isolators which are pipe base-support devices with one or more contained steel springs. Load devices by supported system during operating conditions to produce a minimum static deflection of 1-inch. Equip devices with precompression and vertical-limit features, as well as a minimum 1/4-inch thick elastomer sound pad and isolation washers, for mounting to floor.

Type M: Provide isolators which are elastomer mounted baseplate and riser pipe-guide devices, with contained double acting elastomer elements which under rated load have a minimum static deflection of 3/8-inch. Size isolator to accommodate thermal insulation within the stationary guide ring.

### 2.2 MATERIALS

Ensure rubber is natural rubber and elastomer is chloroprene. Shore A durometer measurement of both materials and range between 40 and 60.

Inorganic materials such as precompressed, high-density, fibrous glass encased in a resilient moisture-impervious membrane may be used in lieu of specified natural rubber and elastomers. Where this substitution is made, ensure specified deflections are modified by the manufacturing source to accommodate physical characteristics of inorganic materials and to provide equal or better vibration isolation.

Ensure weather-exposed metal vibration-isolator parts are corrosion protected. Chloroprene coat springs.

### 2.3 TESTS, INSPECTIONS, AND VERIFICATIONS

Submit test reports for testing vibration isolation for each type of isolator and each type of base. Meet referenced standards contained within this section. Include in test reports allowable deflection and measured deflection also meeting referenced standards within this section.

## PART 3 EXECUTION

### 3.1 INSTALLATION

Install equipment in accordance with manufacturer's recommendations.

Ensure rails, structural steel bases, and concrete inertia blocks are raised not less than 1-inch above the floor and are level when equipment supported is under operating load.

Ensure vibration-isolation installation and deflection testing after equipment start-up is directed by a competent representative of the manufacturer.

### 3.2 FIELD QUALITY CONTROL

#### 3.2.1 Tests and Reports

Ensure vibration-isolation devices are deflection tested. Submit test reports substantiating that all equipment has been isolated as specified



and that minimum specified deflections have been met. Make all measurements in the presence of the Contracting Officer.

-- End of Section --

SECTION 23 05 48.19

SEISMIC BRACING FOR HVAC  
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 CONCRETE INSTITUTE (ACI)

- ACI 355.2 (2007) Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary
- ACI 355.4 (2011) Qualification of Post-Installed Adhesive Anchors in Concrete (ACI 355.4) and Commentary

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 A36/A36M (2019) Standard Specification for Carbon Structural Steel
- ASTM A53/A53M (2022) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
- ASTM A153/A153M (2023) Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- ASTM A325 (2014) Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
- ASTM A490 (2014a) Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
- ASTM A500/A500M (2023) Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
- ASTM A563 (2021; E 2022a) Standard Specification for Carbon and Alloy Steel Nuts

- ASTM A603 (2019) Standard Specification for Zinc-Coated Steel Structural Wire Rope
- ASTM F1554 (2020) Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength
- METAL FRAMING MANUFACTURERS ASSOCIATION (MFMA)
- MFMA-4 (2004) Metal Framing Standards Publication
- 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)
- UFC 3-301-01 (2023; with Change 1, 2023) Structural Engineering
- UFC 4-010-01 (2018) DoD Minimum Antiterrorism Standards for Buildings
- VIBRATION ISOLATION AND SEISMIC CONTROL MANUFACTURERS ASSOCIATION (VISCMA)
- VISCMA 412 (2014) Installing Seismic Restraints for Mechanical Equipment

## 1.2 SYSTEM DESCRIPTION

### 1.2.1 General Requirements

Apply the requirements for seismic protection measures described in this section and on the drawings to the mechanical equipment and mechanical systems both inside and outside of the building along with exterior utilities and systems listed below. Where there is a conflict between the specifications and the drawings, the specifications will take precedence. Accomplish resistance to lateral forces induced by earthquakes without consideration of friction resulting from gravity loads.

### 1.2.2 Mechanical Equipment

Mechanical equipment to be seismically protected must include, but not be limited to, the following items to the extent required on the drawings or in other sections of these specifications:

Boilers	Air Handling Units
Domestic Water Heat Exchanger	Expansion Air Separator Tanks
Thermal Storage Units	Valves and Fittings for Piping

Computer Room Air Conditioners	Pumps with Motors
Unit Heaters	Exhaust, Return and Misc. Fans
Air Terminal Units	Fan Coil Units
Humidifiers	Instrumentation and Control for HVAC
Stacks	Duct Silencers
Air Ducts	Sanitary and Waste Piping
Unit Heaters	Hydronic and Domestic Water, Gas Piping

1.2.3 Mechanical Systems

Mechanical systems to be seismically protected must include the following items to the extent required on the drawings or in this or other sections of these specifications:

- a. All Piping and Ducts Inside the Building Except as Specifically Stated in Article "Items Not Covered By This Section".
- b. Chilled Water Distribution Systems.
- c. Gas Piping Outside of Buildings.
- d. All Water Supply Systems.
- e. Storm and Sanitary Sewer Systems.
- f. All Process Piping.
- g. Heating Water Distribution Systems.
- h. Stacks.

1.2.4 Contractor Designed Bracing

Submit copies of the design calculations with the drawings. Calculations must be approved, certified, stamped and signed by a registered Professional Structural Engineer. Calculations must verify the capability of structural members to which bracing is attached for carrying the load from the brace. Design the bracing in accordance with UFC 3-301-01, UFC 4-010-01 and additional data furnished by the Contracting Officer. Resistance to lateral forces induced by earthquakes must be accomplished without consideration of friction resulting from gravity loads. UFC 3-301-01 uses parameters for the building, not for the equipment in the building; therefore, corresponding adjustments to the formulas must be required. Loadings determined using UFC 3-301-01 are based on strength design. Provide seismic bracing design drawings and engineering calculations for equipment and systems listed in this specification and as required by the contract documents.

### 1.2.5 Items Not Covered By This Section

#### 1.2.5.1 Fire Protection Systems

Install seismic protection of piping for fire protection systems as specified in Section 21 13 13.00 10 WET PIPE SPRINKLER SYSTEM, FIRE PROTECTION.

#### 1.2.5.2 Items Requiring No Seismic Restraints

Seismic restraints are not required for the following items:

- a. Gas piping less than 1 inch nominal pipe size.
- b. Piping in boiler and mechanical equipment rooms less than 1-1/4 inches nominal pipe size.
- c. All other piping equal to or less than 3 inches nominal pipe size.
- d. Rectangular air handling ducts less than 6 square feet in cross sectional area.
- e. Round air handling ducts less than 28 inches in diameter.
- f. Piping suspended by individual hangers 12 inches or less in length from the top of pipe to the bottom of the supporting structural member where the hanger is attached, except as noted below.
- g. Ducts suspended by hangers 12 inches or less in length from the top of the duct to the bottom of the supporting structural member, except as noted below.

In exemptions f. and g. all hangers must meet the length requirements. If the length requirement is exceeded by one hanger in the run, brace the entire run. Seismically protect interior piping and ducts not listed above in accordance with the provisions of this specification.

### 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. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. When shown in this specification, detailed shop drawings for all required equipment, piping and ductwork with calculations certified by a registered structural engineer will be provided. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

#### SD-02 Shop Drawings

Coupling and Bracing

Flexible Couplings or Joints

Equipment Restraint

Contractor Designed Bracing (Including Calculations); G

SD-03 Product Data

Coupling and Bracing; G

Equipment Restraint; G

Contractor Designed Bracing (Including Calculations); G

Vibration Isolators

SD-05 Design Data

Design Calculations

PART 2 PRODUCTS

2.1 GENERAL DESIGN REQUIREMENTS

Submit detailed seismic restraint drawings for mechanical equipment, duct systems, piping systems and any other mechanical systems along with calculations, catalog cuts, templates, and erection and installation details, as appropriate, for the items listed below. Indicate thickness, type, grade, class of metal, and dimensions; and show construction details, reinforcement, anchorage, and installation with relation to the building construction. Calculations must be stamped, by a registered structural engineer, and verify the capability of structural members to which bracing is attached for carrying the load from the brace. Include drawing for Mission Critical Equipment indicating the equipment location in the facility sufficient to be used for the installation. Design must be based on actual equipment and system layout. Design must include calculated dead loads, static seismic loads and capacity of materials utilized for the connection of the equipment or system to the structure. Analysis must detail anchoring methods.

2.2 EQUIPMENT RESTRAINT

Equipment must be rigidly or flexibly mounted as indicated in the specifications and/or drawings depending on vibration isolation requirements as follows below.

Roof mounted equipment, both vibration isolated and nonisolated, must have support members designed and anchored to building structural steel or concrete as required for seismic restraint and wind loads.

2.2.1 Rigidly (Base and Suspended) Mounted Equipment

HVAC equipment furnished under this contract must be rigidly mounted in accordance with ACI 355.2 and ACI 355.4. Anchor bolts must conform to ASTM F1554. For any rigid equipment which is rigidly anchored, provide flexible joints for piping, ductwork, electrical conduit, etc., that are capable of accommodating displacements equal to the full width of the joint in both orthogonal directions. Suspended equipment bracing attachments should be located just above the center of gravity to minimize swinging. Use the ratio of the overturning moment from seismic forces to the resisting moment due to gravity loads to determine if overturning forces need to be considered in the sizing of anchor bolts. Provide calculations to verify the adequacy of the anchor bolts for combined shear

and overturning.

Roof mounted HVAC equipment roof curbs, framing and attachment to equipment and structure must be designed and braced to withstand seismic loads. Designated Seismic Systems (DSS) assigned to Seismic Design Category (SDC) C, D, E, or F and Risk Category IV components needed for continued operation after an earthquake must have two nuts provided on each anchor bolt.

#### 2.2.2 Nonrigid or Flexibly-Mounted Equipment

Select vibration isolation devices so that the maximum movement of equipment from the static deflection point is 1/4 inch. Equipment flexibly mounted on vibration isolators must have a bumper restraint or snubber in each horizontal direction and vertical restraints must be provided where required to resist overturning. Isolator housing and restraints must be constructed of ductile materials. A viscoelastic pad or similar material of appropriate thickness must be used between the bumper and components to limit the impact load. Restraints must be designed to resist the calculated horizontal lateral and vertical forces.

Spring vibration isolators must be seismically rated, restrained isolators for equipment subject to load variations and large external forces. The seismically rated housing must be sized to meet or exceed the force requirements applicable to the project and meet the required isolation criteria. Spring vibration isolator manufacturer's will be a member of VISCMA. Design force,  $F_p$ , must be doubled for vibration isolators with an air gap greater than 0.25 inches as specified in ASCE 7-16, Chapter 13. Housed springs must not be used for seismic restraint applications because they cannot resist uplift.

#### 2.3 BOLTS AND NUTS

Hex head bolts, and heavy hexagon nuts must be ASTM A325 or ASTM A490 bolts and ASTM A563 nuts. Provide bolts and nuts galvanized in accordance with ASTM A153/A153M when used underground or exposed to weather.

#### 2.4 FLEXIBLE JOINTS

Flexible joints must have same pressure and temperature ratings as adjoining pipe. Braided hoses must not be used where there is torsional or axial movement unless manufacturer allows it.

#### 2.5 SWAY BRACING MATERIALS

Material used for members listed in Contract Documents, must be structural steel conforming with the following:

- a. Plates, rods, and rolled shapes, ASTM A36/A36M.
- b. Wire rope, ASTM A603 pre-stretched. Class B galv coating Ferrule clamps must be qualified by testing for use in seismic applications per VISCMA 412. A minimum of two clamps are required on each end of wire rope.
- c. Tubes, ASTM A500/A500M, Grade B.
- d. Pipes, ASTM A53/A53M, Grade B.

- e. Angles, ASTM A36/A36M.
- f. Channels (Struts) with in-turned lips and associated hardware for fastening to channels at random points conforming to MFMA-4

### PART 3 EXECUTION

#### 3.1 COUPLING AND BRACING

- a. Submit detail drawings, as specified here and throughout this specification, along with catalog cuts, templates, and erection and installation details, as appropriate, for the items listed. Submittals must be complete in detail; must indicate thickness, type, grade, class of metal, and dimensions; and must show construction details, reinforcement, anchorage, and installation with relation to the building construction.
- b. Provide coupling installation conforming to the details shown on the drawings. Provisions of this paragraph apply to all piping within a 5 foot line around outside of building unless buried in the ground. Piping grouped for support on trapeze-type hangers must be braced at the most frequent interval as determined by applying the requirements of this specification to each piping run on the common support.
- c. Size bracing components as required for the total load carried by the common supports. Bracing rigidly attached to pipe flanges, or similar, must not be used where it would interfere with thermal expansion of piping.
- d. Adjust isolators and restraints after piping systems has been filled and equipment is at its operating weight, following the manufacturer's written instructions.
- e. Install cables at a 45-degree slope. Where interference is present, the slope may be minimum of 30 degrees or a maximum of 60 degrees per VISCMA 412.

#### 3.2 BUILDING DRIFT

Provide joints capable of accommodating seismic displacements for vertical piping between floors of the building, where pipes pass through a building seismic or expansion joint, or where rigidly supported pipes connect to equipment with vibration isolators. Provide horizontal piping across expansion joints to accommodate the resultant of the drifts of each building unit in each orthogonal direction. For threaded piping, provide swing joints made of the same piping material. For piping with manufactured ball joints the seismic drift must be 0.0198 feet per foot of height above the base where the seismic separation occurs; this drift value must be used in place of the expansion given in the manufacturer's selection table.

#### 3.3 FLEXIBLE COUPLINGS OR JOINTS

##### 3.3.1 Building Piping

Provide flexible couplings or joints in building piping at bottom of all pipe risers for pipe larger than 3-1/2 inches in diameter. Laterally brace flexible couplings or joints without interfering with the action of the flexible coupling or joint. Cast iron waste and vent piping need only



comply with these provisions when caulked joints are used. Flexible bell and spigot pipe joints using rubber gaskets may be used at each branch adjacent to tees and elbows for underground waste piping inside of building to satisfy these requirements.

### 3.3.2 Underground Piping

Install flexible coupling in underground piping and 4 inch or larger conduit, except heat distribution system, where the piping enters the building. Provide couplings that accommodate 1 inch of relative movement between the pipe and the building in any direction. Provide additional flexible couplings where shown on the drawings.

### 3.4 PIPE SLEEVES

Size pipe sleeves in interior non-fire rated walls as indicated on the drawings to provide clearances that will permit differential movement of piping without the piping striking the pipe sleeve. Pipe sleeves in fire rated walls must conform to the requirements in Section 07 84 00 FIRESTOPPING.

### 3.5 SPREADERS

Provide spreaders between adjacent piping runs to prevent contact during seismic activity whenever pipe or insulated pipe surfaces are less than 4 inches apart. Apply spreaders at same interval as sway braces at an equal distance between the sway braces. If rack type hangers are used where the pipes are restrained from contact by mounting to the rack, spreaders are not required for pipes mounted in the rack. Apply spreaders to surface of bare pipe and over insulation on insulated pipes utilizing high-density inserts and pipe protection shields in accordance with the requirements of Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

### 3.6 SWAY BRACES FOR PIPING

Provide sway braces to prevent movement of the pipes under seismic loading. Provide braces in both the longitudinal and transverse directions, relative to the axis of the pipe. Provide sufficient braces for equipment to resist a horizontal force as specified in UFC 3-301-01 without exceeding safe working stress of bracing components. Provide bracing that does not interfere with thermal expansion requirements for the pipes as described in other sections of these specifications. For seismic analysis of horizontal pipes, the equivalent static force should be considered to act concurrently with the full dead load of the pipe, including contents.

#### 3.6.1 Transverse Sway Bracing

Provide transverse sway bracing for steel and copper pipe at intervals not to exceed those shown on the drawings. All runs (length of pipe between end joints) must have a minimum of transverse bracing at each end. Provide transverse sway bracing for pipes of materials other than steel and copper at intervals not to exceed the hanger spacing as specified in Section 22 00 00 PLUMBING, GENERAL PURPOSE.

#### 3.6.2 Longitudinal Sway Bracing

Provide longitudinal sway bracing at 40 foot intervals unless otherwise indicated. All runs (length of pipe between end joints) must have one

longitudinal brace minimum. Construct sway braces in accordance with the drawings. Do not use branch lines, walls, or floors as sway braces.

### 3.6.3 Vertical Runs

Run is defined as length of pipe between end joints. Do not brace vertical runs of piping no more than 10 foot vertical intervals. Braces for vertical runs must be above the center of gravity of the segment being braced. Flexible couplings should be provided at the bottoms of risers for pipes larger than 3.5 in. (89 mm) in diameter. Flexible couplings and expansion joints should be braced laterally and longitudinally unless such bracing would interfere with the action of the couplings or joints. When pipes enter buildings, flexible couplings should be provided to allow for relative movement between the soil and building. Construct all sway braces in accordance with the drawings. Attach sway braces to the structural system. Do not connect to branch lines, walls, or floors.

### 3.6.4 Clamps and Hangers

Apply clamps or hangers on uninsulated pipes directly to pipe. Insulated piping must have clamps or hangers applied over insulation in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

Hanger rod stiffener angle or strut bracing must be securely attached by a series of attachment clamps manufactured from a one piece metal stamping and must include all require attachment hardware and locking nuts. Attachment clamps made from aluminum or cast iron must not be used in seismic applications. Do not weld vertical braces to hanger rods.

## 3.7 SWAY BRACES FOR DUCTS

### 3.7.1 Braced Ducts

Provide bracing details and spacing for rectangular and round ducts in accordance with SMACNA 1981. However, the design seismic loadings for these items must not be less than loadings obtained using the procedures in UFC 3-301-01. Bracing must not attach to duct joints. Use shortest screws possible when penetrating ductwork to minimize airflow noise inside duct.

### 3.7.2 Unbraced Ducts

Attach hangers for unbraced ducts to the duct within 2 inches of the top of the duct with a minimum of two #10 sheet metal screws. Install unbraced ducts with a 6 inch minimum clearance to vertical ceiling hanger wires.

-- 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 S1.11 PART 1 (2014) American National Standard  
Electroacoustics - Octave-Band and  
Fractional-Octave-Band Filters - Part 1:  
Specifications

ASA S1.4 (1983; Amendment 1985; R 2006)  
Specification for Sound Level Meters (ASA  
47)

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 (2005) 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 and water 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 systems (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 systems 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/ccb/NAVGRAPH/graphtoc.pdf>

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.

### 1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. Submittals with an "S" are for inclusion in the Sustainability Notebook, 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

DALT and TAB Submittal and Work Schedule; G

TAB Pre-Field Engineering Report; G

DALT and TAB Procedures Summary; G

Completed Pre-Final DALT Work Checklist; 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

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.

It is acceptable for an entire duct system to be DALT'd instead of disassembling that system in order to DALT only the 20 percent portion specified above.

#### 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 and DX 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 Return Air Fans

Return air fan system including fan ducts, plenums, registers, diffusers, grilles, and louvers for supply air, return air, outside air, and mixed air.

#### 3.4.3.4 Fan Coils

Fan coil unit systems including fans, coils, ducts, plenums, and air distribution devices for supply air, return air, and outside air.

#### 3.4.3.5 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 Chilled Water

Chilled water systems including chillers, condensers, cooling towers, pumps, coils, system balance valves and flow measuring devices.

For water chillers, report data as required by AABC, NEBB and TABB standard procedures, including refrigeration operational data.

##### 3.4.4.2 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.

##### 3.4.4.3 Pressure Independent Control Valves

Water flow through hydronic coils shall be verified using the calibrated manual balancing valves provided, regardless of whether or not a pressure independent control valve is present.

#### 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 and generator 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 With Seasonal Limitations

##### 3.4.6.1 Performance Tests

##### 3.4.6.2 Season Of Maximum Load

##### 3.4.6.3 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.

##### 3.4.6.4 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.

#### 3.4.7 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.

#### 3.4.8 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.

#### 3.4.9 TAB Reports

##### 3.4.10 Quality Assurance - COTR TAB Field Acceptance Testing

###### 3.4.10.1 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, sound level readings) 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.

###### 3.4.10.2 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.

#### 3.4.10.3 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

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

ASTM INTERNATIONAL (ASTM)

ASTM A580/A580M (2023) Standard Specification for  
Stainless Steel Wire

ASTM B209 (2014) Standard Specification for Aluminum  
and Aluminum-Alloy Sheet and Plate

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 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 (2013) Standard Specification for Calcium  
Silicate Block and Pipe Thermal Insulation

ASTM C534/C534M (2014) Standard Specification for  
Preformed Flexible Elastomeric Cellular  
Thermal Insulation in Sheet and Tubular  
Form

ASTM C547 (2015) Standard Specification for Mineral  
Fiber Pipe Insulation

ASTM C552 (2016a) Standard Specification for



Cellular Glass Thermal Insulation

ASTM C647	(2008; R 2013) Properties and Tests of Mastics and Coating Finishes for Thermal Insulation
ASTM C795	(2008; R 2013) 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) Standard Practice for Determining the Properties of Jacketing Materials for Thermal Insulation
ASTM D2863	(2019) Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
ASTM D882	(2012) Tensile Properties of Thin Plastic Sheeting
ASTM E2231	(2015) Specimen Preparation and Mounting of Pipe and Duct Insulation Materials to Assess Surface Burning Characteristics
ASTM E84	(2023) Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM E96/E96M	(2022a; E 2023) Standard Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials

FM GLOBAL (FM)

FM APP GUIDE	(updated on-line) Approval Guide <a href="http://www.approvalguide.com/">http://www.approvalguide.com/</a>
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INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 2758	(2014) Paper - Determination of Bursting Strength
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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
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MIDWEST INSULATION CONTRACTORS ASSOCIATION (MICA)

MICA Insulation Stds (1999) National Commercial & Industrial  
Insulation Standards

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 90A (2021) Standard for the Installation of  
Air Conditioning and Ventilating Systems

NFPA 90B (2018) Standard for the Installation of  
Warm Air Heating and Air Conditioning  
Systems

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-A-24179 (1969; Rev A; Am 2 1980; Notice 1 1987)  
Adhesive, Flexible Unicellular-Plastic  
Thermal Insulation

MIL-A-3316 (1987; Rev C; Am 2 1990) Adhesives,  
Fire-Resistant, Thermal Insulation

MIL-PRF-19565 (1988; Rev C) Coating Compounds, Thermal  
Insulation, Fire- and Water-Resistant,  
Vapor-Barrier

UNDERWRITERS LABORATORIES (UL)

UL 723 (2020) UL Standard for Safety Test for  
Surface Burning Characteristics of  
Building Materials

UL 94 (2023; Reprint Jan 2024) UL Standard for  
Safety Tests for Flammability of Plastic  
Materials for Parts in Devices and  
Appliances

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. Field applied insulation materials required for use on Government-furnished items as listed in the SPECIAL CONTRACT REQUIREMENTS shall be furnished and installed by the Contractor.

1.2.2 Recycled Materials

Provide thermal insulation containing recycled materials to the extent practicable, provided that the materials meet all other requirements of this section. The minimum recycled material content of the following insulation are:

Rock Wool	75 percent slag of weight
Fiberglass	20-25 percent glass cullet by weight
Rigid Foam	9 percent recovered material

### 1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. Submittals with an "S" are for inclusion in the Sustainability Notebook, 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  
Equipment Insulation Systems and Associated Accessories

#### SD-03 Product Data

Pipe Insulation Systems; G  
Duct Insulation Systems; G  
Equipment Insulation Systems; G

#### SD-04 Samples

Thermal Insulation; G  
Display Samples; G

#### SD-08 Manufacturer's Instructions

Pipe Insulation Systems; G  
Duct Insulation Systems; G  
Equipment Insulation Systems; G

#### SD-11 Closeout Submittals

Reduce Volatile Organic Compounds (VOC) for Caulking, Sealant and Adhesive Materials; S  
Recycled Content for Pipe and Ductwork Insulation Materials; S

### 1.4 QUALITY ASSURANCE

#### 1.4.1 Installer Qualification

Qualified installers shall have successfully completed three or more similar type jobs within the last 5 years.

### 1.5 DELIVERY, STORAGE, AND HANDLING

Materials shall be delivered in the manufacturer's unopened containers. Materials delivered and placed in storage shall be provided with

protection 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. Packages or standard containers of insulation, jacket material, cements, adhesives, and coatings delivered for use, and samples required for approval shall have manufacturer's stamp or label attached giving the name of the manufacturer and brand, and a description of the material, date codes, and approximate shelf life (if applicable). Insulation packages and containers shall be asbestos free.

## PART 2 PRODUCTS

### 2.1 PRODUCT SUSTAINABILITY CRITERIA

For products in this section, where applicable and to extent allowed by performance criteria, provide and document the following:

#### 2.1.1 Reduce Volatile Organic Compounds (VOC) for Caulking, Sealant and Adhesive Materials

For interior applications, provide caulking, sealant and adhesive materials meeting the reduced VOC requirements as stated within Section 01 33 29 SUSTAINABILITY REPORTING paragraph REDUCE VOLATILE ORGANIC COMPOUNDS (VOC).

#### 2.1.2 Recycled Content for Pipe and Ductwork Insulation Materials

Provide documentation in conformance with Section 01 33 29 SUSTAINABILITY REPORTING that the following products meet the recycled content requirements as outlined in this section:

- a. Pipe Insulation Systems
- b. Duct Insulation Systems

### 2.2 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. The product number, k-value, thickness and furnished accessories including adhesives, sealants and jackets for each mechanical system requiring insulation shall be included. The product data must be copyrighted, have an identifying or publication number, and shall have been published prior to the issuance date of this solicitation. Materials furnished under this section shall be submitted together in a booklet.

#### 2.2.1 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.

### 2.2.2 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. Flame spread, and smoke developed indexes, shall be determined 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.

### 2.3 MATERIALS

Provide insulation that meets or exceed the requirements of ASHRAE 90.1 - IP. Insulation exterior shall be cleanable, grease resistant, non-flaking and non-peeling. Materials shall be compatible and shall not contribute to corrosion, soften, or otherwise attack surfaces to which applied in either wet or dry state. Materials to be used on stainless steel surfaces shall meet ASTM C795 requirements. Calcium silicate shall not be used on chilled or cold water systems. Materials shall be asbestos free. Provide product recognized under UL 94 (if containing plastic) and listed in FM APP GUIDE.

#### 2.3.1 Adhesives

##### 2.3.1.1 Acoustical Lining Insulation Adhesive

Adhesive shall be a nonflammable, fire-resistant adhesive conforming to ASTM C916, Type I.

##### 2.3.1.2 Mineral Fiber Insulation Cement

Cement shall be in accordance with ASTM C195.

##### 2.3.1.3 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. Lagging adhesives shall be nonflammable and fire-resistant and shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84. Adhesive shall be MIL-A-3316, Class 1, pigmented white and be 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. Lagging adhesives shall be applied in strict accordance with the manufacturer's recommendations for pipe and duct insulation.

##### 2.3.1.4 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. The adhesive shall not adversely affect, initially or in service, the insulation to which it is applied, nor shall it cause any corrosive effect on metal to which it is applied. Any solvent dispersing medium or volatile component of the adhesive shall have no objectionable

odor and shall not contain any benzene or carbon tetrachloride. The dried adhesive shall 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 shall be nonflammable and fire resistant. Flexible Elastomeric Adhesive: Comply with MIL-A-24179, Type II, Class I. Provide product listed in FM APP GUIDE.

### 2.3.2 Caulking

ASTM C920, Type S, Grade NS, Class 25, Use A.

### 2.3.3 Corner Angles

Nominal 0.016 inch aluminum 1 by 1 inch with factory applied kraft backing. Aluminum shall be ASTM B209, Alloy 3003, 3105, or 5005.

### 2.3.4 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, properly installed protective vapor retarder/barriers and vapor stops shall be used on high relative humidity and below ambient temperature applications to reduce movement of moisture through or around the insulation to the colder interior surface.

### 2.3.5 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.

### 2.3.6 Fibrous Glass Cloth and Glass Tape

Fibrous glass cloth, with 20X20 maximum mesh size, and glass tape shall have maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84. Tape shall be 4 inch wide rolls. Class 3 tape shall be 4.5 ounces/square yard. Elastomeric Foam Tape: Black vapor-retarder foam tape with acrylic adhesive containing an anti-microbial additive.

### 2.3.7 Staples

Outward clinching type monel .

### 2.3.8 Jackets

#### 2.3.8.1 Aluminum Jackets

Aluminum jackets shall be corrugated, embossed or smooth sheet, 0.016 inch nominal thickness; ASTM B209, Temper H14, Temper H16, Alloy 3003, 5005, or 3105. Corrugated aluminum jacket shall not be used outdoors. Aluminum jacket securing bands shall 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 shall be 2 by 0.016 inch aluminum matching jacket material. Bands for insulation below ground shall be 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, the bands at the circumferential joints shall be designed by the manufacturer to seal the joints and hold the jacket in place.

#### 2.3.8.2 Polyvinyl Chloride (PVC) Jackets

Polyvinyl chloride (PVC) jacket and fitting covers shall have high impact strength, ultraviolet (UV) resistant rating or treatment and moderate chemical resistance with minimum thickness 0.030 inch.

#### 2.3.8.3 Vapor Barrier/Weatherproofing Jacket

Vapor barrier/weatherproofing jacket shall be laminated self-adhesive, 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.

#### 2.3.8.4 Vapor Barrier/Vapor Retarder

Apply the following criteria to determine which system is required.

- a. On ducts, piping and equipment operating below 60 degrees F or located outside shall be equipped with a vapor barrier.
- b. Ducts, pipes and equipment that are located inside and that always operate above 80 degrees F shall be installed with a vapor retarder where required as stated in paragraph VAPOR RETARDER REQUIRED.

#### 2.3.9 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. Jackets used on insulation exposed in finished areas shall 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. All non-metallic jackets shall 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.

##### 2.3.9.1 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. The product shall meet all physical property and performance requirements of ASTM C1136, Type I,

except the burst strength shall be a minimum of 85 psi. ASTM D2863 Limited Oxygen Index (LOI) shall be a minimum of 31.

In addition, neither the outer exposed surface nor the inner-most surface contacting the insulation shall be paper or other moisture-sensitive material. The outer exposed surface shall be white and have an emittance of not less than 0.80. The outer exposed surface shall be paintable.

#### 2.3.9.2 Vapor Retarder/Vapor Barrier Mastic Coatings

##### 2.3.9.2.1 Vapor Barrier

The vapor barrier shall 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. Permeability shall be less than 0.02 when tested in accordance with ASTM E96/E96M. Products shall meet UL 723 or ASTM E84 flame and smoke requirements and shall be UV resistant.

##### 2.3.9.2.2 Vapor Retarder

The vapor retarder coating shall be fire and water resistant and appropriately selected for either outdoor or indoor service. Color shall be white. The water vapor permeance of the compound shall be 0.013 perms or less at 43 mils dry film thickness as determined according to procedure B of ASTM E96/E96M utilizing apparatus described in ASTM E96/E96M. The coating shall be nonflammable, fire resistant type. Coating shall meet MIL-PRF-19565 Type II (if selected for indoor service) and be Qualified Products Database listed. All other application and service properties shall be in accordance with ASTM C647.

##### 2.3.9.3 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. Vapor retarder shall have 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.

##### 2.3.9.4 Polyvinylidene Chloride (PVDC) Film Vapor Retarder

The PVDC film vapor retarder shall have 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.

##### 2.3.9.5 Polyvinylidene Chloride Vapor Retarder Adhesive Tape

Requirements must meet the same as specified for Laminated Film Vapor Retarder above.



#### 2.3.9.6 Vapor Barrier/Weather Barrier

The vapor barrier shall be 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). Vapor barrier shall meet 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). Tape shall be as specified for laminated film vapor barrier above.

#### 2.3.10 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. Jacket shall have a maximum flame spread index of 25 and a maximum smoke developed index of 50 when tested in accordance with ASTM E84.

#### 2.3.11 Wire

Soft annealed ASTM A580/A580M Type 302, 304 or 316 stainless steel, 16 or 18 gauge.

#### 2.3.12 Insulation Bands

Insulation bands shall be 1/2 inch wide; 26 gauge stainless steel.

#### 2.3.13 Sealants

Sealants shall be chosen from the butyl polymer type, the styrene-butadiene rubber type, or the butyl type of sealants. Sealants shall have 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.

### 2.4 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 90.1 - IP. Comply with EPA requirements for material with recycled content in accordance with Section 01 33 29 SUSTAINABILITY REPORTING, paragraph RECYCLED CONTENT. Limit pipe insulation materials to those listed herein and meeting the following requirements:

#### 2.4.1 Aboveground Cold Pipeline ( -30 to 60 deg. F)

Insulation for outdoor, indoor, exposed or concealed applications, shall be as follows:

##### 2.4.1.1 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.

#### 2.4.1.2 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. Type I and II shall 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.

#### 2.4.1.3 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.

#### 2.4.2 Aboveground Hot Pipeline (Above 60 deg. F)

Insulation for outdoor, indoor, exposed or concealed applications shall meet the following requirements. Supply the insulation with manufacturer's recommended factory-applied jacket/vapor barrier.

##### 2.4.2.1 Mineral Fiber

ASTM C547, Types I, II or III, supply the insulation with manufacturer's recommended factory-applied jacket.

##### 2.4.2.2 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.

##### 2.4.2.3 Cellular Glass

ASTM C552, Type II and Type III. Supply the insulation with manufacturer's recommended factory-applied jacket.

##### 2.4.2.4 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.

#### 2.4.3 Below-ground Pipeline Insulation

For below-ground pipeline insulation, use cellular glass, ASTM C552, type II.

### 2.5 DUCT INSULATION SYSTEMS

#### 2.5.1 Field or Shop Applied Insulation

Provide field or shop-applied ASTM C534/C534M Grade 1, Type II, flexible elastomeric closed cell insulation according to manufacturer's recommendations for insulation with insulation manufacturer's standard reinforced fire-retardant vapor barrier.

#### 2.5.1.1 Rigid Insulation

Calculate the minimum thickness in accordance with ASHRAE 90.1 - IP.

#### 2.5.1.2 Blanket Insulation

Calculate minimum thickness in accordance with ASHRAE 90.1 - IP.

#### 2.5.2 Acoustical Duct Lining

##### 2.5.2.1 General

For ductwork indicated or specified in Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM 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).

##### 2.5.2.2 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.

#### 2.5.3 Duct Insulation Jackets

##### 2.5.3.1 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.

##### 2.5.3.2 Metal Jackets

###### 2.5.3.2.1 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.

###### 2.5.3.3 Vapor Barrier/Weatherproofing Jacket

Vapor barrier/weatherproofing jacket shall be 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).

#### 2.5.4 Weatherproof Duct Insulation

Provide ASTM C534/C534M Grade 1, Type II, flexible elastomeric cellular 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.

## 2.6 EQUIPMENT INSULATION SYSTEMS

Insulate equipment and accessories as specified in Tables 5 and 6. In outside locations, provide insulation 1/2 inch thicker than specified. Increase the specified insulation thickness for equipment where necessary to equal the thickness of angles or other structural members to make a smooth, exterior surface. Submit a booklet containing manufacturer's published installation instructions for the insulation systems. The instructions must be copyrighted, have an identifying or publication number, and shall have been published prior to the issuance date of this solicitation. A booklet is also required by paragraphs titled: Pipe Insulation Systems and Duct Insulation Systems.

## PART 3 EXECUTION

### 3.1 APPLICATION - GENERAL

Insulation shall only be applied to unheated and uncooled piping and equipment. Flexible elastomeric cellular insulation shall not be compressed at joists, studs, columns, ducts, hangers, etc. The insulation shall not pull apart after a one hour period; any insulation found to pull apart after one hour, shall be replaced.

#### 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. Each material used shall be identified, 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. Approved display sample sections shall remain 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

Display sample sections shall 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, material shall be installed in accordance with the manufacturer's written instructions. Insulation materials shall not be applied until tests and heat tracing specified in other sections of this specification are completed. Material such as rust, scale, dirt and moisture shall be removed from surfaces to receive insulation. Insulation shall be kept clean and dry. Insulation shall not be removed from its shipping containers until the day it is ready to use and shall be returned to like containers or equally protected from dirt and moisture at the end of each workday. Insulation that becomes dirty shall be thoroughly cleaned prior to use. If insulation becomes wet or if cleaning does not restore the surfaces to like new condition, the insulation will be rejected, and shall be immediately removed from the jobsite. Joints shall be staggered on multi layer insulation. Mineral fiber thermal insulating cement shall be mixed with demineralized water when used on stainless steel surfaces. Insulation, jacketing and accessories shall be installed 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, the penetration shall be sealed 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. Firestopping materials be furnished and installed by the Firestopping installer and shall conform to the requirements in Section 07 84 00 FIRESTOPPING.

### 3.1.4 Painting and Finishing

Painting shall be 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. Flexible elastomeric cellular insulation shall not be used 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. Insulation seals at seams and joints shall not be capable of being pulled apart one hour after application. Insulation that can be pulled apart one hour after installation shall be replaced.

### 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

No welding shall be done on piping, duct or equipment 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/Equipment That Require Insulation

Insulation is required on all pipes, ducts, or equipment, except for omitted items as specified.

## 3.2 PIPE INSULATION SYSTEMS INSTALLATION

### 3.2.1 Pipe Insulation

#### 3.2.1.1 General

Pipe insulation shall be installed 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. Installation shall be with full length units of insulation and using a single cut piece to complete a run. Cut pieces or scraps abutting each other shall not be used. Pipe insulation shall be omitted on the following:

- a. Pipe used solely for fire protection.
- b. Chromium plated pipe to plumbing fixtures. However, fixtures for use by the physically handicapped shall have the hot water supply and drain, including the trap, insulated where exposed.
- c. Sanitary drain lines.
- d. Adjacent insulation.
- e. ASME stamps.
- f. Access plates of fan housings.
- g. Cleanouts or handholes.

#### 3.2.1.2 Pipes Passing Through Walls, Roofs, and Floors

Pipe insulation shall be continuous 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

The 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 shall extend 2 inches beyond either side of the wall and shall be secured 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 from 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. The escutcheon plate shall overlap 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 shall seal the end of the insulation. The annular space between the outer surface of the pipe insulation and caulk 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. The escutcheon plate shall overlap the wall penetration by at least 3/8 inches.

### 3.2.1.3 Pipes Passing Through Hangers

Insulation, whether hot or cold application, shall be continuous through hangers. All horizontal pipes 2 inches and smaller shall be supported 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, insulation inserts as specified below for piping larger than 2 inches shall be installed, 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. An insulation insert of cellular glass, prefabricated insulation pipe hangers, or perlite above 80 degrees F shall be installed above each shield. The insert shall cover not less than the bottom 180-degree arc of the pipe. Inserts shall be the same thickness as the insulation, and shall 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. The insulation jacket shall be 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. An insulation insert of cellular glass or calcium silicate shall be installed between each shield and the pipe. The insert shall cover the 360-degree arc of the pipe. Inserts shall be the same thickness as the insulation, and shall 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. The insulation jacket shall be continuous over the wooden dowel, wooden block, or insulation insert. The vertical weight of the pipe shall be supported with hangers located in a horizontal section of the pipe. When the pipe riser is longer than 30 feet, the weight of the pipe shall be additionally supported with hangers in the vertical run of the pipe that are directly clamped to the pipe, penetrating the pipe insulation. These hangers shall be insulated and the insulation jacket sealed 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. The jacket material used to cover inserts in flexible elastomeric cellular insulation shall conform 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

Flexible elastomeric cellular pipe insulation shall be tubular form for pipe sizes 6 inches and less. Grade 1, Type II sheet insulation used on pipes larger than 6 inches shall not be stretched around the pipe. On pipes larger than 12 inches, the insulation shall be adhered directly to the pipe on the lower 1/3 of the pipe. Seams shall be staggered when applying multiple layers of insulation. Sweat fittings shall be insulated with miter-cut pieces the same size as on adjacent piping. Screwed fittings shall be insulated with sleeved fitting covers fabricated from miter-cut pieces and shall be overlapped and sealed 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, 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) jackets shall be utilized. Pipe insulation to the 6 foot level shall be protected. All exposed insulated pipes, valves and fittings located in mechanical rooms in addition to the 6 foot level laminate specified herein before shall be 100 percent jacketed with color coded PVC jackets as specified in Article "Polyvinyl Chloride (PVC) Jackets". all insulation and jackets shall be installed to not interfere with the operation of valves.

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 90.1 - IP.

TABLE 1					
Insulation Material for Piping					
Service					
	Material	Specification	Type	Class	VR/VB Req'd
Chilled Water (Supply & Return Piping, 40 F nominal)					
	Cellular Glass	ASTM C552	II	2	Yes

TABLE 1					
Insulation Material for Piping					
Service					
	Material	Specification	Type	Class	VR/VB Req'd
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		Yes
	Mineral Fiber with Wicking Material. Do not use in applications exposed to outdoor ambient conditions in climatic zones 1 through 4.	ASTM C547	I		Yes
Heating Hot Water Supply & Return (Max 250 F)					
	Flexible Elastomeric Cellular	ASTM C534/C534M	I	2	No
	Calcium Silicate	ASTM C533	I		No
	Cellular Glass	ASTM C552	II	2	No
	Mineral Fiber	ASTM C547	I	1	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)					
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No
	Cellular Glass	ASTM C552	II	2	No
	Mineral Fiber	C547	I	1	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
	Cellular Glass	ASTM C552	III		Yes
Condensate Drain Located Inside Building					
	Flexible Elastomeric Cellular	ASTM C534/C534M	I		No

TABLE 1					
Insulation Material for Piping					
Service					
	Material	Specification	Type	Class	VR/VB Req'd
	Cellular Glass	ASTM C552	II	2	No

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, Piping, 40 Degrees F nominal)						
	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)						
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
	Calcium Silicate	2.5	2.5	3	3	3
	Cellular Glass	2	2.5	3	3	3
	Mineral Fiber	1.5	1.5	2	2	2
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)						
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A

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	2	2
	Mineral Fiber	1	1	1	1.5	1.5
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)						
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
	Cellular Glass	1.5	1.5	1.5	1.5	1.5
Condensate Drain Located Inside Building						
	Flexible Elastomeric Cellular	1	1	1	N/A	N/A
	Cellular Glass	1.5	1.5	1.5	1.5	1.5

3.2.2 Aboveground Cold Pipelines

The following cold pipelines for minus 30 to plus 60 degrees F, shall be insulated 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. Air conditioner condensate drains.
- f. Exposed lavatory drains and domestic water lines serving plumbing fixtures for handicap persons.
- g. Domestic cold water.

### 3.2.2.1 Insulation Material and Thickness

Insulation thickness for cold pipelines shall be determined using Table 2.

### 3.2.2.2 Factory or Field applied Jacket

Insulation shall be covered 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. Insulation inside the building, to be protected with an aluminum jacket or greater than 3ply vapor barrier/weatherproofing self-adhesive (minimum 2 mils adhesive, 3 mils embossed) product, less than 0.0000 permeability, standard grade, Embossed Silver, White & Black, shall have the insulation and vapor retarder jacket installed as specified herein. The aluminum jacket or greater than 3ply vapor barrier/weatherproofing self-adhesive (minimum 2 mils adhesive, 3 mils embossed) product, less than 0.0000 permeability, standard grade, embossed silver, White & Black, shall be installed 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, aluminum jackets or greater than 3ply vapor barrier/weatherproofing self-adhesive (minimum 2 mils adhesive, 3 mils embossed) product, less than 0.0000 permeability, standard grade, embossed silver, white & black, shall be provided for pipe insulation to the 6 ft level. All exposed insulated pipes, valves and fittings located in mechanical rooms in addition to the 6 foot level laminate specified herein before shall be 100% jacketed with color coded PVC jackets as specified in Article "Polyvinyl Chloride (PVC) Jackets". All insulation and jackets shall be installed to not interfere with the operation of valves.

### 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 - less than 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 only the butt joints shall be secured 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. Pipe insulation shall be tightly butted to the insulation of the fittings and accessories. The butted joints and ends shall be sealed with joint sealant and sealed with a vapor retarder coating or PVDC adhesive tape or greater than 3 ply laminate jacket - less than 0.0000 perm adhesive tape.
- b. Precut or preformed insulation shall be placed around all fittings and accessories and shall 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 shall 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. Insulation of the same thickness and conductivity as the adjoining pipe insulation shall be used. If nesting size insulation is used, the insulation shall be overlapped 2 inches or one pipe diameter. Elbows insulated using segments shall 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, or equipment insulating system, after approval of materials and prior to applying insulation.

- (1) The MICA plates shall 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. The MICA plates shall 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, the detail drawings shall be 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 shall 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. Tape seams shall overlap 1 inch. The coating shall extend out onto the adjoining pipe insulation 2 inches. Fabricated insulation with a factory vapor retarder jacket shall be protected 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, the joints shall be sealed with a vapor retarder coating and a 4 inch wide ASJ tape which matches the jacket of the pipe insulation.
- d. Anchors attached directly to the pipe shall be insulated for a sufficient distance to prevent condensation but not less than 6 inches from the insulation surface.
- e. Insulation shall be marked showing the location of unions, strainers, and check valves.

#### 3.2.2.5 Optional PVC Fitting Covers

Where PVC fitting jackets are not required by Contract Documents, 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. Factory precut or premolded insulation segments shall be used under the fitting covers for elbows. Insulation segments shall be the same insulation as the pipe insulation including same density, thickness, and thermal conductivity. The covers shall be secured by PVC vapor retarder tape, adhesive, seal welding or with tacks made for securing PVC covers. Seams in the cover, and tacks and laps to adjoining pipe insulation jacket, shall be sealed 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

All hot pipe lines above 60 degrees F, except those piping listed in subparagraph Pipe Insulation in PART 3 as to be omitted, shall be insulated in accordance with Table 2. This includes but is not limited to the following:

- a. Domestic hot water supply & re-circulating system.
- b. Hot water heating.
- c. Exposed refrigerant liquid lines.

Insulation shall be covered, 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

Pipe insulation shall be tightly butted to the insulation of the fittings and accessories. The butted joints and ends shall be sealed with joint sealant. Insulation shall be marked showing 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. Insulation shall be 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. Insulation of the same thickness and conductivity as the adjoining pipe insulation shall be used. If nesting size insulation is used, the insulation shall be overlapped 2 inches or one pipe diameter. Elbows insulated using segments shall conform to MICA Tables 12.20 "Mitered Insulation Elbow".

### 3.2.4 Piping Exposed to Weather

Piping exposed to weather shall be insulated and jacketed as specified for the applicable service inside the building. After this procedure, 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 or PVC jacket shall be applied. PVC jacketing requires no factory-applied jacket beneath it, however an all service jacket shall be applied if factory applied jacketing is not furnished. Flexible elastomeric cellular insulation exposed to weather shall be treated 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. The jacket shall



overlap not less than 2 inches at longitudinal and circumferential joints and shall be secured with bands at not more than 12 inch centers. Longitudinal joints shall be overlapped down to shed water and located at 4 or 8 o'clock positions. Joints on piping 60 degrees F and below shall be sealed 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, joints shall be caulked to prevent moisture penetration. Joints on piping above 60 degrees F shall be sealed with a moisture retarder.

#### 3.2.4.2 Insulation for Fittings

Flanges, unions, valves, fittings, and accessories shall be insulated and finished as specified for the applicable service. Two coats of breather emulsion type weatherproof mastic (impermeable to water, permeable to air) recommended by the insulation manufacturer shall be applied with glass tape embedded between coats. Tape overlaps shall be not less than 1 inch and the adjoining aluminum jacket not less than 2 inches. Factory preformed aluminum jackets may be used in lieu of the above. Molded PVC fitting covers shall be provided when PVC jackets are used for straight runs of pipe. PVC fitting covers shall have adhesive welded joints and shall be 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

PVC jacket shall be ultraviolet resistant and adhesive welded weather tight with manufacturer's recommended adhesive. Installation shall include provision for thermal expansion.

#### 3.2.5 Below Ground Pipe Insulation

Below ground pipes shall be insulated 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. Domestic hot water.
- b. Domestic cold water.
- c. Chilled water.

##### 3.2.5.1 Type of Insulation

Below ground pipe shall be insulated 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. Bore surfaces of the insulation shall be coated with a thin coat of gypsum cement of a type recommended by the insulation manufacturer. Coating thickness shall be sufficient to fill surface cells of insulation. Mastic type materials shall not be used 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. Stainless steel bands, 3/4 inch wide by 0.020 inch thick shall be used to secure insulation in place. A minimum of two bands per section of insulation shall be applied. As an alternate, fiberglass reinforced tape may be used to secure insulation on piping up to 12 inches in diameter. A minimum of two bands per section of insulation shall be applied.
- c. Insulation shall terminate at anchor blocks but shall be continuous through sleeves and manholes.
- d. At point of entry to buildings, underground insulation shall be terminated 2 inches inside the wall or floor, shall butt tightly against the aboveground insulation and the butt joint shall be sealed with high temperature silicone sealant and covered with fibrous glass tape.
- e. Provision for expansion and contraction of the insulation system shall be made in accordance with the insulation manufacturer's recommendations.
- f. Flanges, couplings, valves, and fittings shall be insulated with factory pre-molded, prefabricated, or field-fabricated sections of insulation of the same material and thickness as the adjoining pipe insulation. Insulation sections shall be secured as recommended by the manufacturer.
- g. Insulation, including fittings, shall be finished with three coats of asphaltic mastic, with 6 by 5.5 mesh synthetic reinforcing fabric embedded between coats. Fabric shall be overlapped a minimum of 2 inches at joints. Total film thickness shall be a minimum of 3/16 inch. As an alternate, a prefabricated bituminous laminated jacket, reinforced with internal reinforcement mesh, shall be applied to the insulation. Jacketing material and application procedures shall 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). Application procedures shall match the manufacturer's written instructions.
- h. At termination points, other than building entrances, the mastic and cloth or tape shall 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, corner angles shall be installed on external corners of insulation on ductwork in exposed finished spaces before covering with jacket.

#### 3.3.1 Duct Insulation Minimum Thickness

Duct insulation minimum thickness in accordance with Table 4.

Table 4 - Minimum Duct Insulation (inches)	
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

Insulation and vapor retarder/vapor barrier shall be provided for the following cold air ducts and associated equipment.

- a. Supply ducts.
- b. Return air ducts.
- c. Relief ducts.
- d. Plenums.
- e. Duct-mounted coil casings.
- f. Coil headers and return bends.
- g. Coil casings.
- h. Fresh air intake ducts.
- i. Ducts exposed to weather.
- j. Combustion air intake ducts.

Insulation for rectangular ducts shall be flexible type where concealed, minimum density 3/4 pcf, and rigid type where exposed, minimum density 3 pcf. Insulation for both concealed or exposed round/oval ducts shall be 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. Insulation for all exposed ducts shall be provided with either a white, paint-able, factory-applied Type I jacket or a field applied vapor retarder/vapor barrier jacket coating finish as specified, the total field applied dry film thickness shall be approximately 1/16 inch. Insulation on all concealed duct shall be provided with a factory-applied Type I or II vapor retarder/vapor barrier jacket. Duct insulation shall be continuous through sleeves and prepared openings except firewall penetrations. Duct insulation terminating at fire dampers, shall 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. Duct insulation and vapor retarder/vapor barrier shall cover the collar, neck, and any un-insulated surfaces of diffusers, registers and grills. Vapor retarder/vapor barrier materials shall be applied to form a complete unbroken vapor seal over the

insulation. Sheet Metal Duct shall be sealed in accordance with Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM.

### 3.3.2.1 Installation on Concealed Duct

- a. For rectangular, oval or round ducts, flexible insulation shall be attached 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 insulation shall be additionally secured to bottom of ducts by the use of mechanical fasteners. Fasteners shall be spaced on 16 inch centers and not more than 16 inches from duct corners.
- c. For rectangular, oval and round ducts, mechanical fasteners shall be provided on sides of duct risers for all duct sizes. Fasteners shall be spaced on 16 inch centers and not more than 16 inches from duct corners.
- d. Insulation shall be impaled on the mechanical fasteners (self stick pins) where used and shall be pressed thoroughly into the adhesive. Care shall be taken to ensure vapor retarder/vapor barrier jacket joints overlap 2 inches. The insulation shall not be compressed to a thickness less than that specified. Insulation shall be carried over standing seams and trapeze-type duct hangers.
- e. Where mechanical fasteners are used, self-locking washers shall be installed and the pin trimmed and bent over.
- f. Jacket overlaps shall be secured with staples and tape as necessary to ensure a secure seal. Staples, tape and seams shall be coated 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. Breaks in the jacket material shall be covered with patches of the same material as the vapor retarder jacket. The patches shall extend not less than 2 inches beyond the break or penetration in all directions and shall be secured with tape and staples. Staples and tape joints shall be sealed 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, voids in the insulation shall be filled and the penetration sealed 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. Insulation terminations and pin punctures shall be sealed and flashed with a reinforced vapor retarder coating finish or tape with a brush coat of vapor retarder coating.. The coating shall overlap the adjoining insulation and un-insulated surface 2 inches. Pin puncture coatings shall extend 2 inches from the puncture in all directions.
- j. Where insulation standoff brackets occur, insulation shall be extended under the bracket and the jacket terminated at the bracket.

### 3.3.2.2 Installation on Exposed Duct Work

- a. For rectangular ducts, rigid insulation shall be secured to the duct by mechanical fasteners on all four sides of the duct, spaced not more than 12 inches apart and not more than 3 inches from the edges of the insulation joints. A minimum of two rows of fasteners shall be provided for each side of duct 12 inches and larger. One row shall be provided for each side of duct less than 12 inches. Mechanical fasteners shall be as corrosion resistant as G60 coated galvanized steel, and shall 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, insulation shall be brought up to standing seams, reinforcing, and other vertical projections and shall not be carried over. Vapor retarder/barrier jacket shall be continuous across seams, reinforcing, and projections. When height of projections is greater than the insulation thickness, insulation and jacket shall be carried over. Apply insulation with joints tightly butted. Neatly bevel insulation around name plates and access plates and doors.
- c. Impale insulation on the fasteners; self-locking washers shall be installed and the pin trimmed and bent 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. Breaks and ribs or standing seam penetrations in the jacket material shall be covered with a patch of the same material as the jacket. Patches shall extend not less than 2 inches beyond the break or penetration and shall be secured with tape and stapled. Staples and joints shall be sealed with a brush coat of vapor retarder coating.
- f. At jacket penetrations such as hangers, thermometers, and damper operating rods, the voids in the insulation shall be filled and the penetrations sealed with a flashing sealant.
- g. Insulation terminations and pin punctures shall be sealed and flashed with a reinforced vapor retarder coating finish. The coating shall overlap the adjoining insulation and un-insulated surface 2 inches. Pin puncture coatings shall extend 2 inches from the puncture in all directions.
- h. Oval and round ducts, flexible type, shall be insulated with factory Type I jacket insulation with minimum density of 3/4 pcf, attached as in accordance with MICA standards.

### 3.3.3 Insulation for Warm Air Duct

Insulation and vapor barrier shall be provided for the following warm air ducts and associated equipment:.

- a. Supply ducts.
- b. Return air ducts.
- c. Relief air ducts

- d. Plenums.
- e. Duct-mounted coil casings.
- f. Coil-headers and return bends.
- g. Fresh air intake ducts.
- h. Ducts exposed to weather.

Insulation for rectangular ducts shall be flexible type where concealed, and rigid type where exposed. Insulation on exposed ducts shall be provided with a white, paint-able, factory-applied Type II jacket, or finished with adhesive finish. Flexible type insulation shall be used for round ducts, with a factory-applied Type II jacket. Insulation on concealed duct shall be provided with a factory-applied Type II jacket. Adhesive finish where indicated to be used shall be accomplished by applying two coats of adhesive with a layer of glass cloth embedded between the coats. The total dry film thickness shall be approximately 1/16 inch. Duct insulation shall be continuous through sleeves and prepared openings. Duct insulation shall terminate at fire dampers and flexible connections.

#### 3.3.3.1 Installation on Concealed Duct

- a. For rectangular, oval and round ducts, insulation shall be attached 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, insulation shall be secured to the bottom of ducts by the use of mechanical fasteners. Fasteners shall be spaced on 18 inch centers and not more than 18 inches from duct corner.
- c. For rectangular, oval and round ducts, mechanical fasteners shall be provided on sides of duct risers for all duct sizes. Fasteners shall be spaced on 18 inch centers and not more than 18 inches from duct corners.
- d. The insulation shall be impaled on the mechanical fasteners where used. The insulation shall not be compressed to a thickness less than that specified. Insulation shall be carried over standing seams and trapeze-type hangers.
- e. Self-locking washers shall be installed where mechanical fasteners are used and the pin trimmed and bent over.
- f. Insulation jacket shall overlap not less than 2 inches at joints and the lap shall be secured and stapled on 4 inch centers.

#### 3.3.3.2 Installation on Exposed Duct

- a. For rectangular ducts, the rigid insulation shall be secured to the duct by the use of mechanical fasteners on all four sides of the duct, spaced not more than 16 inches apart and not more than 6 inches from the edges of the insulation joints. A minimum of two rows of fasteners shall be provided 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. Duct insulation with factory-applied jacket shall be formed with minimum jacket seams, and each piece of rigid insulation shall be fastened to the duct using mechanical fasteners. When the height of projection is less than the insulation thickness, insulation shall be brought up to standing seams, reinforcing, and other vertical projections and shall not be carried over the projection. Jacket shall be continuous across seams, reinforcing, and projections. Where the height of projections is greater than the insulation thickness, insulation and jacket shall be carried over the projection.
- c. Insulation shall be impaled on the fasteners; self-locking washers shall be installed and pin trimmed and bent over.
- d. Joints on jacketed insulation shall be sealed with a 4 inch wide strip of tape and brushed with vapor retarder coating.
- e. Breaks and penetrations in the jacket material shall be covered with a patch of the same material as the jacket. Patches shall extend not less than 2 inches beyond the break or penetration and shall be secured with adhesive and stapled.
- f. Insulation terminations and pin punctures shall be sealed with tape and brushed with vapor retarder coating.
- g. Oval and round ducts, flexible type, shall be insulated with factory Type I jacket insulation, minimum density of 3/4 pcf attached by staples spaced not more than 16 inches and not more than 6 inches from the degrees of joints. Joints shall be sealed 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, ducts shall be insulated as specified for cold air duct.

#### 3.3.5 Duct Test Holes

After duct systems have been tested, adjusted, and balanced, breaks in the insulation and jacket shall be repaired in accordance with the applicable section of this specification for the type of duct insulation to be repaired.

#### 3.3.6 Duct Exposed to Weather

##### 3.3.6.1 Installation

Ducts exposed to weather shall be insulated and finished as specified for the applicable service for exposed duct inside the building. After the above is accomplished, the insulation shall then be further finished as detailed in the following subparagraphs.

##### 3.3.6.2 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 shall 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 shall be applied with the joints lapped not less than 3 inches and secured with bands located at circumferential laps and at not more than 12 inch intervals throughout. Horizontal joints shall lap down to shed water and located at 4 or 8 o'clock position. Joints shall be sealed with metal jacketing sealant to prevent moisture penetration. Where jacketing abuts an un-insulated surface, joints shall be sealed with metal jacketing sealant.

#### 3.3.6.3 Fittings

Fittings and other irregular shapes shall be finished as specified for rectangular ducts.

#### 3.3.6.4 Rectangular Ducts

Two coats of weather barrier mastic reinforced with fabric or mesh for outdoor application shall be applied to the entire surface. Each coat of weatherproof mastic shall be 1/16 inch minimum thickness. The exterior shall be a metal jacketing applied for mechanical abuse and weather protection, and secured 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. Membrane shall be applied overlapping material by 3 inches. No bands or caulking needed-see manufacturing recommend installation instructions.

### 3.4 EQUIPMENT INSULATION SYSTEMS INSTALLATION

#### 3.4.1 General

Removable insulation sections shall be provided to cover parts of equipment that must be opened periodically for maintenance including vessel covers, fasteners, flanges and accessories. Equipment insulation shall be omitted on the following:

- a. Hand-holes.
- b. Boiler manholes.
- c. Cleanouts.
- d. ASME stamps.
- e. Manufacturer's nameplates.
- f. Duct Test/Balance Test Holes.

#### 3.4.2 Insulation for Cold Equipment

Cold equipment below 60 degrees F: Insulation shall be furnished on equipment handling media below 60 degrees F including the following:

- a. Pumps.
- b. Drip pans under chilled equipment.
- c. Water softeners.



- d. Duct mounted coils.
- e. Cold and chilled water pumps.
- i. Roof drain bodies.
- g. Air handling equipment parts that are not factory insulated.
- h. Expansion and air separation tanks.
- i. Brazed plate heat exchangers.
- j. Chilled water buffer tank.
- k. Chilled water expansion tank and air separator.

3.4.2.1 Insulation Type

Insulation shall be suitable for the temperature encountered. Material and thicknesses shall be as shown in Table 5:

TABLE 5		
Insulation Thickness for Cold Equipment (inches)		
Equipment handling media at indicated temperature		
	Material	Thickness (inches)
35 to 60 degrees F		
	Flexible Elastomeric Cellular	1
	Cellular Glass	1.5
1 to 34 degrees F		
	Flexible elastomeric Cellular	1.5
	Cellular Glass	3
Minus 30 to 0 degrees F		
	Flexible Elastomeric Cellular	1.75
	Cellular Glass	3.5

3.4.2.2 Pump Insulation

- a. Insulate pumps by forming a box around the pump housing. The box shall be constructed by forming the bottom and sides using joints that do not leave raw ends of insulation exposed. Joints between sides and between sides and bottom shall be joined by adhesive with lap strips for rigid mineral fiber and contact adhesive for flexible elastomeric cellular insulation. The box shall conform to the requirements of MICA Insulation Stds plate No. 49 when using flexible elastomeric

cellular insulation. Joints between top cover and sides shall fit tightly forming a female shiplap joint on the side pieces and a male joint on the top cover, thus making the top cover removable.

- b. Exposed insulation corners shall be protected with corner angles.
- c. Upon completion of installation of the insulation, including removable sections, two coats of vapor retarder coating shall be applied with a layer of glass cloth embedded between the coats. The total dry thickness of the finish shall be 1/16 inch. A parting line shall be provided between the box and the removable sections allowing the removable sections to be removed without disturbing the insulation coating. Flashing sealant shall be applied to parting line, between equipment and removable section insulation, and at all penetrations.

#### 3.4.2.3 Other Equipment

- a. Insulation shall be formed or fabricated to fit the equipment. To ensure a tight fit on round equipment, edges shall be beveled and joints shall be tightly butted and staggered.
- b. Insulation shall be secured in place with bands or wires at intervals as recommended by the manufacturer but not more than 12 inch centers except flexible elastomeric cellular which shall be adhered with contact adhesive. Insulation corners shall be protected under wires and bands with suitable corner angles.
- c. Cellular glass shall be installed in accordance with manufacturer's instructions. Joints and ends shall be sealed with joint sealant, and sealed with a vapor retarder coating.
- d. Insulation on heads of heat exchangers shall be removable. Removable section joints shall be fabricated using a male-female shiplap type joint. The entire surface of the removable section shall be finished by applying two coats of vapor retarder coating with a layer of glass cloth embedded between the coats. The total dry thickness of the finish shall be 1/16 inch.
- e. Exposed insulation corners shall be protected with corner angles.
- f. Insulation on equipment with ribs shall be applied over 6 by 6 inches by 12 gauge welded wire fabric which has been cinched in place, or if approved by the Contracting Officer, spot welded to the equipment over the ribs. Insulation shall be secured to the fabric with J-hooks and 2 by 2 inches washers or shall be securely banded or wired in place on 12 inch centers.

#### 3.4.2.4 Vapor Retarder/Vapor Barrier

Upon completion of installation of insulation, penetrations shall be caulked. Two coats of vapor retarder coating or vapor barrier jacket shall be applied over insulation, including removable sections, with a layer of open mesh synthetic fabric embedded between the coats. The total dry thickness of the finish shall be 1/16 inch. Flashing sealant or vapor barrier tape shall be applied to parting line between equipment and removable section insulation.

3.4.3 Insulation for Hot Equipment

Insulation shall be furnished on equipment handling media above 60 degrees F including the following:

- a. Converters.
- b. Heat exchangers.
- c. Pumps handling media above 130 degrees F.
- d. Hot water buffer tanks.
- e. Air separation tanks and expansion tanks.
- f. Unjacketed boilers or parts of boilers.

3.4.3.1 Insulation

Insulation shall be suitable for the temperature encountered. Shell and tube-type heat exchangers shall be insulated for the temperature of the shell medium.

Insulation thickness for hot equipment shall be determined using Table 6:

TABLE 6		
Insulation Thickness for Hot Equipment (inches)		
Equipment handling water or media at indicated temperature limit		
	Material	Thickness (inches)
250 degrees F		
	Flexible Elastomeric Cellular (<200 F)	1
	Rigid Mineral Fiber	2
	Flexible Mineral Fiber	2
	Calcium Silicate	4
	Cellular Glass	3

3.4.3.2 Insulation of Pumps

Insulate pumps by forming a box around the pump housing. The box shall be constructed by forming the bottom and sides using joints that do not leave raw ends of insulation exposed. Bottom and sides shall be banded to form a rigid housing that does not rest on the pump. Joints between top cover and sides shall fit tightly. The top cover shall have a joint forming a female shiplap joint on the side pieces and a male joint on the top cover, making the top cover removable. Two coats of Class I adhesive shall be applied over insulation, including removable sections, with a layer of glass cloth embedded between the coats. A parting line shall be provided between the box and the removable sections allowing the removable sections

to be removed without disturbing the insulation coating. The total dry thickness of the finish shall be 1/16 inch. Caulking shall be applied to parting line of the removable sections and penetrations.

#### 3.4.3.3 Other Equipment

- a. Insulation shall be formed or fabricated to fit the equipment. To ensure a tight fit on round equipment, edges shall be beveled and joints shall be tightly butted and staggered.
- b. Insulation shall be secured in place with bands or wires at intervals as recommended by the manufacturer but not greater than 12 inch centers except flexible elastomeric cellular which shall be adhered. Insulation corners shall be protected under wires and bands with suitable corner angles.
- c. On high vibration equipment, cellular glass insulation shall be set in a coating of bedding compound as recommended by the manufacturer, and joints shall be sealed with bedding compound. Mineral fiber joints shall be filled with finishing cement.
- d. Insulation on heads of heat exchangers shall be removable. The removable section joint shall be fabricated using a male-female shiplap type joint. Entire surface of the removable section shall be finished as specified.
- e. Exposed insulation corners shall be protected with corner angles.
- f. On equipment with ribs, such as boiler flue gas connection, draft fans, and fly ash or soot collectors, insulation shall be applied over 6 by 6 inch by 12 gauge welded wire fabric which has been cinched in place, or if approved by the Contracting Officer, spot welded to the equipment over the ribs. Insulation shall be secured to the fabric with J-hooks and 2 by 2 inch washers or shall be securely banded or wired in place on 12 inch (maximum) centers.
- g. On equipment handling media above 600 degrees F, insulation shall be applied in two or more layers with joints staggered.
- h. Upon completion of installation of insulation, penetrations shall be caulked. Two coats of adhesive shall be applied over insulation, including removable sections, with a layer of glass cloth embedded between the coats. The total dry thickness of the finish shall be 1/16 inch. Caulking shall be applied to parting line between equipment and removable section insulation.

#### 3.4.4 Equipment Handling Dual Temperature Media

Below and above 60 degrees F: equipment handling dual temperature media shall be insulated as specified for cold equipment.

#### 3.4.5 Equipment Exposed to Weather

##### 3.4.5.1 Installation

Equipment exposed to weather shall be insulated and finished in accordance with the requirements for ducts exposed to weather in paragraph DUCT INSULATION INSTALLATION.

#### 3.4.5.2 Optional Panels

At the option of the Contractor, prefabricated metal insulation panels may be used in lieu of the insulation and finish previously specified. Thermal performance shall be equal to or better than that specified for field applied insulation. Panels shall be the standard catalog product of a manufacturer of metal insulation panels. Fastenings, flashing, and support system shall conform to published recommendations of the manufacturer for weatherproof installation and shall prevent moisture from entering the insulation. Panels shall be designed to accommodate thermal expansion and to support a 250 pound walking load without permanent deformation or permanent damage to the insulation. Exterior metal cover sheet shall be aluminum and exposed fastenings shall be stainless steel or aluminum.

-- End of Section --

SECTION 23 09 00

INSTRUMENTATION AND CONTROL FOR HVAC

11/15

PART 1 GENERAL

1.1 SUMMARY

Provide a complete BACnet Direct Digital Control (DDC) system, except for the Font End which is specified in Section 25 10 10, UTILITY MONITORING AND CONTROL suitable for the control of the heating, ventilating and air conditioning (HVAC) and other building-level systems for each facility 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, Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END INTEGRATION and other referenced Sections.

1.1.1 System Requirements

Provide systems meeting the requirements of 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.
- 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.

#### 1.1.2 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.

#### 1.1.3 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.

#### 1.1.4 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
- b. Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC
- c. Section 01 91 00.15 TOTAL BUILDING COMMISSIONING
- d. SctSection25 05 11.01 CYBERSECURITY FOR LOW IMPACT HVAC CONTROL SYSTEMS
- e. Section 25 10 10, UTILITY MONITORING AND CONTROL.

### 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 (2017) 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 (2021) Standard for the Installation of  
Air Conditioning and Ventilating Systems

UNDERWRITERS LABORATORIES (UL)

UL 5085-3 (2006; Reprint Nov 20121) 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.

##### 1.4.1 Alarm Generation

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).

In BACnet, Alarm Generation is the creation of alarm events using Event Reporting as defined in ASHRAE 135 in one of three ways:

- a. Intrinsic Alarm Generation using Intrinsic Reporting
- b. Local Algorithmic Alarm Generation using Algorithmic Reporting where the referenced property is in the same device as the Event Enrollment Object
- c. Remote Algorithmic Alarm Generation using Algorithmic Alarming where the referenced property is in a different device than the Event Enrollment Object.

##### 1.4.2 Building Automation and Control Network (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)

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)

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)

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)

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

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

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)

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

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)

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

One or more physical segments interconnected by repeaters (ASHRAE 135).

1.4.13 BACnet Smart Actuator (B-SA)

A simple actuator device with limited resources intended for specific applications.

1.4.14 BACnet Smart Sensor (B-SS)

A simple sensing device with limited resources.

1.4.15 BACnet Testing Laboratories (BTL)

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

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

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

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)

The network connecting all DDC Hardware within a building (or specific group of buildings).

1.4.20 Building Point of Connection (BPOC)

The Building Control System is a stand alone system with front end and does not have a BPOC.

1.4.21 Commandable

See Overridable.

1.4.22 Commandable Objects

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

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

A graphical representation of control logic for multiple processes that make up a system.

#### 1.4.25 Device

A Digital Controller that contains a BACnet Device Object and uses BACnet to communicate with other devices.

#### 1.4.26 Device Object

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

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

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)

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 Energy Management and control System (EMCS)

A BACnet Direct Digital Control System.

#### 1.4.31 Field Point of Connection (FPOC)

The building level DDC System shall not communicate with any base UMCS.

#### 1.4.32 Gateway

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.

#### 1.4.33 IEEE 802.3 Ethernet

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.

#### 1.4.34 Internet Protocol (IP, TCP/IP, UDP/IP)

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.

#### 1.4.35 Input/Output (I/O)

Physical inputs and outputs to and from a device, although the term sometimes describes network or "virtual" inputs or outputs. See also "Points".

#### 1.4.36 I/O Expansion Unit

An I/O expansion unit provides additional point capacity to a digital controller

#### 1.4.37 IP subnet

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.

#### 1.4.38 Local-Area Network (LAN)

A communication network that spans a limited geographic area and uses the same basic communication technology throughout.

#### 1.4.39 Local Display Panels (LDPs)

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.

#### 1.4.40 MAC Address

Media Access Control address. The physical device address that identifies a device on a Local Area Network.

1.4.41 Master-Slave/Token-Passing (MS/TP)

Data link protocol as defined by the BACnet standard. Multiple speeds (data rates) are permitted by the BACnet MS/TP standard.

1.4.42 Monitoring and Control (M&C) Software

The '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.

1.4.43 Network Number

A site-specific number assigned to each network. This network number must be unique throughout the BACnet internetwork.

1.4.44 Object

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.

1.4.45 Object Identifier

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.

1.4.46 Object Instance

See paragraph OBJECT IDENTIFIER

1.4.47 Object Properties

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.

1.4.48 Operator Configurable

For BACnet systems, a property, setting, or value in a device is Operator Configurable when it is Configurable and is either:

- a. a Writeable Property of a Standard BACnet Object; or
- b. a Property of a Standard BACnet Object that is Writeable when Out\_Of\_Service is TRUE and Out\_Of\_Service is Writeable.

1.4.49 Override

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.

#### 1.4.50 Performance Verification Test (PVT)

The procedure for determining if the installed DDC SYSTEM 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.

#### 1.4.51 Physical Segment

A single contiguous medium to which BACnet devices are attached (ASHRAE 135).

#### 1.4.52 Polling

A device periodically requesting data from another device.

#### 1.4.53 Points

Physical and virtual inputs and outputs. See also paragraph INPUT/OUTPUT (I/O).

#### 1.4.54 Proportional, Integral, and Derivative (PID) Control Loop

Three parameters used to control modulating equipment to maintain a setpoint. Derivative control is often not required for HVAC systems (leaving "PI" control).

#### 1.4.55 Proprietary

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.

#### 1.4.56 Protocol Implementation Conformance Statement (PICS)

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.

#### 1.4.57 Repeater

A device that connects two control network segments and retransmits all information received on one side onto the other.

#### 1.4.58 Router

A device that connects two 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 control inter network and to control bandwidth usage.

#### 1.4.59 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.

#### 1.4.60 Standard BACnet Objects

Objects with Object\_Type values below 128 and specifically enumerated in Clause 21 of ASHRAE 135. Objects which are not proprietary. See paragraph PROPRIETARY.

#### 1.4.61 Standard BACnet Properties

Properties with Property\_Identifier values below 512 and specifically enumerated in Clause 21 of ASHRAE 135. Properties which are not proprietary. See Proprietary.

#### 1.4.62 Standard BACnet Services

ASHRAE 135 services other than ConfirmedPrivateTransfer or UnconfirmedPrivateTransfer. See paragraph PROPRIETARY.

#### 1.4.63 Writeable Property

A Property is Writeable 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 writeable when the Out of Service Property is TRUE; for purposes of this Section, Properties that are only writeable when the Out of Service Property is TRUE are not considered to be Writeable.

### 1.5 PROJECT SEQUENCING

TABLE I: 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 I 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 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)
1	S	DDC Contractor Design Drawings	
2	S	Manufacturer's Product Data	
3	S	Pre-construction QC Checklist	
4	E	Install Building Control System	AAO #1 thru #3
5	E	Start-Up and Start-Up Testing	ACO #4
6	S	Post-Construction QC Checklist	ACO #5
7	S	Programming Software Configuration Software Programming Software Configuration Software	ACO #5
8	S	Draft As-Built Drawings Draft LNS Database	ACO #5
9	S	Start-Up Testing Report	ACO #5
10	S	PVT Procedures	before schedule start of #11 and AAO #9
11	E	Execute PVT	AAO #8 and #10
12	S	PVT Report	ACO #11
13	S	Controller Application Programs Controller Configuration Settings	AAO #12

TABLE I. PROJECT SEQUENCING			
ITEM #	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY OR DEADLINE FOR)
14	S	Final As-Built Drawings	AAO #12
15	S	O&M Instructions	AAO #14
16	S	Training Documentation	AAO #9 and before scheduled start of #17
17	E	Training	AAO #15 and #16
18	S	Closeout QC Checklist	ACO #17

1.6 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. Submittals with an "S" are for inclusion in the Sustainability Notebook, 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

Contractor Design Drawings; G

Contractor Design Drawings as a single complete package: 2 hard copies and 2 copies on CDROM. Submit hardcopy drawings on ISO A1 34 by 22 inches sheets, and electronic drawings in PDF and in AutoCAD 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.

Draft As-Built Drawings; G

Draft As-Built Drawings as a single complete package: 2 hard copies and 2 copies on CDROM. Submit hardcopy drawings on ISO A1 34 by 22 inches sheets, and electronic drawings in PDF and in AutoCAD 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.

Final As-Built Drawings; G

Final As-Built Drawings as a single complete package: 2 hard copies and 2 copies on CDROM. Submit hardcopy drawings on ISO A1 34 by 22 inches sheets, and electronic drawings in PDF and in AutoCAD 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.

SD-03 Product Data

Programming Software; G

Submit Programming Software on CD-ROM as a Technical Data Package. Submit 2 hard copies of the software user manual for each piece of software.

Controller Application Programs; G

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.

Configuration Software; G

Submit Configuration Software on CD-ROM as a Technical Data Package. Submit 2 hard copies of the software user manual for each piece of software.

Controller Configuration Settings; G

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.

Manufacturer's Product Data; G

Submit Manufacturer's Product Data on CD-ROM.

SD-06 Test Reports

Start-Up Testing Report; G

PVT Procedures; G

PVT Report; G

Four copies of the PVT Report. The PVT Report may be submitted as a Technical Data Package.

Pre-Construction Quality Control (QC) Checklist; G

Four copies of the Pre-Construction QC Checklist.

Post-Construction Quality Control (QC) Checklist; G

Four copies of the Post-Construction QC Checklist.

SD-10 Operation and Maintenance Data

Operation and Maintenance (O&M) Instructions; G

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.

Training Documentation; G

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.

SD-11 Closeout Submittals

Enclosure Keys; G

Password Summary Report; G

Provide Two hardcopies of the Password Summary Report, each copy in its own sealed envelope.

Closeout Quality Control (QC) Checklist; G

Four copies of the Closeout QC Checklist.

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 programing 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 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.

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.

### 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.

### 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.

## 1.9 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.

### 1.9.1 Pre-Construction Quality Control (QC) Checklist

Complete items indicated as Pre-Construction QC Checklist items in the QC Checklist.

### 1.9.2 Post-Construction Quality Control (QC) Checklist

Complete items indicated as Post-Construction QC Checklist items in the QC Checklist.

### 1.9.3 Closeout Quality Control (QC) Checklist

Complete items indicated as Closeout QC Checklist items in the 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, Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END INTEGRATION, 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, Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END INTEGRATION, or this Section. Provide product data for all products in a single indexed compendium, organized by product type. 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.

## 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 32 and 120 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 4 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 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, Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END INTEGRATION, 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 Contracting Officer. Provide a Password Summary Report documenting the password for each device and describing the procedure to change the password for each device.

#### 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.

- a. Submit Contractor Design Drawings consisting of each drawing indicated with pre-construction information depicting the intended control system design and plans.

- b. Submit Draft As-Built Drawings consisting of each drawing indicated updated with as-built data for the system prior to PVT.
- c. Submit Final As-Built Drawings consisting of each drawing indicated updated with all final as-built data.

Sample drawings in electronic format are available via a link in the "Graphical Table of Contents" online at: <http://www.wbdg.org/ccb/NAVGRAPH/graphtoc.pdf>. These drawings may prove useful in demonstrating expected drawing formatting and example content and are provided for illustrative purposes only. These drawings do not meet the content requirements of this Section.

### 3.2.1 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.

### 3.2.2 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.

### 3.2.3 Valve Schedule

Provide a valve schedule containing each valve's unique identifier, size, flow coefficient 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.

### 3.2.4 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.

### 3.2.5 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.

### 3.2.6 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.

### 3.2.7 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.

### 3.2.8 DDC Hardware Schedule

Provide a single DDC Hardware Schedule for the entire project and including following information for each device.

#### 3.2.8.1 DDC Hardware Identifier

The Unique DDC Hardware Identifier for the device.

#### 3.2.8.2 HVAC System

The system "name" used to identify a specific system (the name used on the system schematic drawing for that system).

#### 3.2.8.3 Device Object Identifier

The Device Object Identifier: The Object\_Identifier of the Device Object

#### 3.2.8.4 Network Number

The Network Number for the device.

#### 3.2.8.5 MAC Address

The MAC Address for the device

#### 3.2.8.6 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.

#### 3.2.8.7 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.

#### 3.2.8.8 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.

#### 3.2.8.9 Scheduling Information

Indicate whether the device is used for scheduling.

#### 3.2.8.10 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.

#### 3.2.9 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:

##### 3.2.9.1 Point Name

The abbreviated name for the point using the indicated naming convention.

##### 3.2.9.2 Description

A brief functional description of the point such as "Supply Air Temperature".

##### 3.2.9.3 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.

##### 3.2.9.4 Settings

The value and units of any setpoints, configured setpoints, configuration parameters, and settings related to each point.

#### 3.2.9.5 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.

#### 3.2.9.6 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.

#### 3.2.9.7 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.

#### 3.2.9.8 Network Data Exchange Information (Gets Data From, Sends Data To)

Provide the DDC Hardware Identifier of other DDC Hardware the point is shared with.

#### 3.2.9.9 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.

#### 3.2.9.10 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.

#### 3.2.9.11 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.)

#### 3.2.9.12 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.

#### 3.2.10 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.

#### 3.2.11 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.

#### 3.2.12 Sequences of Operation

Provide HVAC control system sequence of operation and in the same format as the Contract Drawings. Within these drawings, refer to devices by their unique identifiers. Submit sequences of operation for each HVAC system.

#### 3.2.13 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 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 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. 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.

## 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.

### 3.7 MAINTENANCE AND SERVICE

Provide services, materials and equipment as necessary to maintain the entire system in an operational state as indicated for a period of one year after successful completion and acceptance of the Performance Verification Test. Minimize impacts on facility operations.

- a. The integration of the system specified in this section into a Utility Monitoring and Control System must not, of itself, void the warranty or otherwise alter the requirement for the one year maintenance and service period. Integration into a UMCS includes but is not limited to establishing communication between devices in the control system and the front end or devices in another system.
- b. The changing of configuration properties must not, of itself, void the warranty or otherwise alter the requirement for the one year maintenance and service period.

#### 3.7.1 Description of Work

Provide adjustment and repair of the system including the manufacturer's required sensor and actuator (including transducer) calibration, span and range adjustment.

#### 3.7.2 Personnel

Use only service personnel qualified to accomplish work promptly and satisfactorily. Advise the Government in writing of the name of the designated service representative, and of any changes in personnel.

#### 3.7.3 Scheduled Inspections

Perform two inspections at six-month intervals and provide work required. Perform inspections in June and December. During each inspection perform the indicated tasks:

- a. Perform visual checks and operational tests of equipment.
- b. Clean control system equipment including interior and exterior surfaces.
- c. Check and calibrate each field device. Check and calibrate 50 percent of the total analog inputs and outputs during the first inspection. Check and calibrate the remaining 50 percent of the analog inputs and outputs during the second major inspection. Certify analog test instrumentation accuracy to be twice the specified accuracy of the device being calibrated. Randomly check at least 25 percent of all binary inputs and outputs for proper operation during the first inspection. Randomly check at least 25 percent of the remaining binary inputs and outputs during the second inspection. If more than 20 percent of checked inputs or outputs failed the calibration check during any inspection, check and recalibrate all inputs and outputs during that inspection.
- d. Run system software diagnostics and correct diagnosed problems.

- e. Resolve any previous outstanding problems.

#### 3.7.4 Scheduled Work

This work must be performed during regular working hours, Monday through Friday, excluding Federal holidays.

#### 3.7.5 Emergency Service

The Government will initiate service calls when the system is not functioning properly. Qualified personnel must be available to provide service to the system. A telephone number where the service supervisor can be reached at all times must be provided. Service personnel must be at the site within 24 hours after receiving a request for service. The control system must be restored to proper operating condition as required per Section 01 78 00 CLOSEOUT SUBMITTALS.

#### 3.7.6 Operation

After performing scheduled adjustments and repairs, verify control system operation as demonstrated by the applicable tests of the performance verification test.

#### 3.7.7 Records and Logs

Keep dated records and logs of each task, with cumulative records for each major component, and for the complete system chronologically. Maintain a continuous log for all devices, including initial analog span and zero calibration values and digital points. Keep complete logs and provide logs for inspection onsite, demonstrating that planned and systematic adjustments and repairs have been accomplished for the control system.

#### 3.7.8 Work Requests

Record each service call request as received and include 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. Submit a record of the work performed within 5 days after work is accomplished.

#### 3.7.9 System Modifications

Submit recommendations for system modification in writing. Do not make system modifications, including operating parameters and control settings, without prior approval of the Government.

### 3.8 TRAINING

Conduct a training course for 16 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.

### 3.8.1 Training Documentation

Prepare training documentation consisting of:

- a. Course Attendee List: Develop the list of course attendees in coordination with and signed by the HVAC 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.

### 3.8.2 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. 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 workstation 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 acknowledgments
- 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

**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 Writeable are Writeable and Overrides have been provided as indicated	___
<div style="display: flex; justify-content: space-between;"> <span>_____</span> <span>_____</span> </div>		
(QC Representative Signature)		(Date)

-- End of Section --



SECTION 23 09 13

INSTRUMENTATION AND CONTROL DEVICES FOR HVAC

11/15

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 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEMS

Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC

Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES 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 B40.100 (2013) Pressure Gauges and Gauge Attachments

#### FLUID CONTROLS INSTITUTE (FCI)

- FCI 70-2 (2013) 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

#### NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

- ANSI C12.20 (2015; E 2018) Electricity Meters - 0.1, 0.2, and 0.5 Accuracy Classes
- NEMA/ANSI C12.10 (2011) Physical Aspects of Watthour Meters - Safety Standards

#### NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- NFPA 70 (2023; ERTA 7 2023; TIA 23-15) National Electrical Code
- NFPA 90A (2021) 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 Nov 2012) 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 0 to 112 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 ball valves.

#### 2.4.2 Valve Flow Coefficient and Flow Characteristic

##### 2.4.2.1 Two-Way Modulating Valves

Provide the valve performance indicated. Provide equal-percentage flow characteristic.

#### 2.4.3 Two-Position Valves

Use full line size full port valves with maximum available (Cv).

#### 2.4.4 Ball Valves

##### 2.4.4.1 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.

#### 2.4.5 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. PICV shall have a FCI 70-2 Class 4 shut-off rating for all sizes. PICV shall maintain proportional/linear flow coil characteristics. The rated minimum differential pressure for steady flow must not exceed 5 psid across the PICV. Provide ball type valves. PICV shall incorporate control, balancing and flow limiting functions. 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. PICV combination of actuator, internal differential pressure regulator (DPRV) action and trim shall provide minimum close-off pressure rating of 150 percent of total systems (pump) head.

#### 2.4.6 Duct-Coil and Terminal-Unit-Coil Valves

For duct or terminal-unit coils provide control valves with either flare-type or screw 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 galvanized 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.

### 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 Chilled Water

Plus or minus 0.8 degrees F over the range of 35 to 65 degrees F.

##### 2.6.3.1.6 Heating Hot 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

Provide minimum 3 inch immersion. 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 Differential Pressure Instrumentation

##### 2.6.5.1 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

##### 2.6.5.2 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.

#### 2.6.6 Flow Sensors

##### 2.6.6.1 Airflow Sensors (AFMS)

###### 2.6.6.1.1 Airflow Straightener

Provide AFMSs which contain an airflow straightener if required by the AFMS manufacturer's published installation instructions or if there is any duct obstruction, transition, or other fitting within 5 duct diameters upstream of the AFMS. The straightener must be contained inside a flanged sheet metal casing, with the AFMS located as specified according to the published recommendation of the AFMS manufacturer. 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.

###### 2.6.6.1.2 Resistance to Airflow

The resistance to air flow through the AFMS, including the airflow straightener must not exceed 0.085 inch water gauge at an airflow of 2,000 fpm. AFMS construction must be suitable for operation at airflows of up to 5000 fpm over a temperature range of 0 to 120 degrees F.

###### 2.6.6.1.3 Outside Air Temperature

In outside air measurement or in low-temperature air delivery applications, provide an AFMS certified by the manufacturer to be accurate as specified over a temperature range of 0 to 120 degrees F.

###### 2.6.6.1.4 Pitot Tube AFMS

Each Pitot Tube AFMS 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 AFMS manufacturer.

- a. Pitot Tube AFMSs must have an air flow measurement accuracy of plus or minus 2 percent of reading over a range of 125 to 2500 fpm.

###### 2.6.6.1.5 Electronic AFMS

Each electronic AFMS 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 AFMS manufacturer. Electronic AFMSs must have an air flow measurement 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 0 to 212 degrees F.

#### 2.6.6.1.6 Fan Inlet Measurement Devices

Fan inlet measurement devices cannot be used unless indicated on the drawings, schedules, or otherwise specified.

#### 2.6.6.2 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.

#### 2.6.6.3 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.

#### 2.6.6.4 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.

#### 2.6.7 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.

##### 2.6.7.1 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.

##### 2.6.7.2 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.

#### 2.6.7.3 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.

#### 2.6.7.4 Energy Metering

##### 2.6.7.4.1 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.

##### 2.6.7.4.2 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 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.

#### 2.6.9 Emergency Air Distribution Shut-off Switch

Provide emergency air distribution shut-off switches where indicated on the drawings. Switches shall be the mushroom push button type and shall be

provided with a see-through flip-up plastic cover. Provide red lettering on a white background stating "EMERGENCY AIR DISTRIBUTION SHUT-OFF SWITCH". The Emergency air distribution shut-off switch shall be configured to shut-down all required systems and close all required dampers, even if the local hand/off/auto switch is in the hand position, within 30 seconds of switch activation. Select emergency air distribution shut-off switches to be easily distinguished from a fire alarm pull station.

#### 2.6.10 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.

##### 2.6.10.1 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.

##### 2.6.10.2 Ultrasonic Occupancy Sensors

Ultrasonic sensors must operate at a minimum frequency 32 kHz and must be designed to not interfere with hearing aids.

##### 2.6.10.3 Dual-Technology Occupancy Sensor (PIR and Ultrasonic)

Dual-Technology Occupancy Sensors must meet the requirements of both PIR and Ultrasonic Occupancy Sensors.

#### 2.6.11 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.

#### 2.6.12 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.

#### 2.6.13 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.

#### 2.6.14 Temperature Switch

##### 2.6.14.1 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.

##### 2.6.14.2 Pipe Mount Temperature Limit Switch (Aquistat)

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.

#### 2.6.15 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.

### 2.7 INDICATING DEVICES

All indicating devices must display readings in English (inch-pound) units.

### 2.7.1 Thermometers

Provide bi-metal type thermometers at locations indicated. Thermometers must have either 9 inch long scales or 3.5 inch diameter dials, with insertion, immersion, or averaging elements. Provide matching thermowells for pipe-mounted installations. Select scale ranges suitable for the intended service, with the normal operating temperature near the scale's midpoint. The thermometer's accuracy must be plus or minus 2 percent of the scale range.

#### 2.7.1.1 Piping System Thermometers

Piping system thermometers must have brass, malleable iron or aluminum alloy case and frame, clear protective face, permanently stabilized glass tube with indicating-fluid column, white face, black numbers, and a 9 inch scale. Piping system thermometers must have an accuracy of plus or minus 1 percent of scale range. Thermometers for piping systems must have rigid stems with straight, angular, or inclined pattern. Thermometer stems must have expansion heads as required to prevent breakage at extreme temperatures. On rigid-stem thermometers, the space between bulb and stem must be filled with a heat-transfer medium.

#### 2.7.1.2 Air-Duct Thermometers

Air-duct thermometers must have perforated stem guards and 45-degree adjustable duct flanges with locking mechanism.

### 2.7.2 Pressure Gauges

Provide pipe-mounted pressure gauges at the locations indicated. Gauges must conform to ASME B40.100 and have a 4 inch diameter dial and shutoff cock. Select scale ranges suitable for the intended service, with the normal operating pressure near the scale's midpoint. The gauge's accuracy must be plus or minus 2 percent of the scale range.

Gauges must be suitable for field or panel mounting as required, must have black legend on white background, and must have a pointer traveling through a 270-degree arc. Gauge range must be suitable for the application with an upper end of the range not to exceed 150 percent of the design upper limit. Accuracy must be plus or minus 3 percent of scale range. Gauges must meet requirements of ASME B40.100.

#### 2.7.3 Low Differential Pressure Gauges

Gauges for low differential pressure measurements must be a minimum of 3.5 inch (nominal) size with two sets of pressure taps, and must have a diaphragm-actuated pointer, white dial with black figures, and pointer zero adjustment. Gauge range must be suitable for the application with an upper end of the range not to exceed 150 percent of the design upper limit. Accuracy must be plus or minus two percent of scale range.

## 2.8 OUTPUT DEVICES

### 2.8.1 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 for two way control valves 2" and larger shall be provided with limit switches and contacts to permit remote monitoring of valve position (open/close). Modulating electric actuators shall 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.

#### 2.8.1.1 Valve Actuators

Valve actuators must provide shutoff pressures and torques as indicated on the Valve Schedule.

#### 2.8.1.2 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.

#### 2.8.1.3 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 mA<sub>dc</sub> 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.

#### 2.8.2 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.

#### 2.9 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.

#### 2.10 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.

##### 2.10.1 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.

##### 2.10.2 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 AFMS 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 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 54 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 (AFMS)

Locate Outside Air AFMSs downstream from the Outside Air filters.

Install AFMSs 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 AFMS 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 Local Gauges for Actuators

Provide a pressure gauge at each pneumatic control input and output. Pneumatic actuators must have an accessible and visible pressure gauge installed in the tubing lines at the actuator as indicated.

##### 3.1.14.2 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.

-- End of Section --



SECTION 23 09 23.02

BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS  
**02/19**

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.
- 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 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.
- 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 mA<sub>dc</sub> or 0-10 V<sub>dc</sub>. 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 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.

### PART 3 EXECUTION

#### 3.1 CONTROL SYSTEM INSTALLATION

##### 3.1.1 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. 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 viaa 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.

##### 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 ROICC 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 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 external 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 ofASHRAE 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. 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

Provide a schedule for each AHU including its associated Terminal Units.

#### 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

#### 3.1.3.3 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 11 25

FACILITY GAS PIPING  
11/08

PART 1 GENERAL

1.1 SUMMARY

This specification section applies to incidental underground piping under building and above ground steel piping both outside (up to 5 feet beyond exterior walls) and within buildings in compliance with NFPA 54/AGA Z223.1, "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 Z223.1 (2012) National Fuel Gas Code

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI Z21.15/CSA 9.1 (2009; Addenda A 2012, Addenda B 2013; R 2014) Manually Operated Gas Valves for Appliances, Appliance Connector Valves and Hose End Valves

ANSI Z21.18/CSA 6.3 (2007; Addenda A 2010; Addenda B 2012; R 2013) Gas Appliance Pressure Regulators

ANSI Z21.21/CSA 6.5 (2015) Automatic Valves for Gas Appliances

ANSI Z21.24/CSA 6.10 (2006; R 2011) Connectors for Gas Appliances

ANSI Z21.41/CSA 6.9 (2014) Quick-Disconnect Devices for Use with Gas Fuel Appliances

ANSI Z21.69/CSA 6.16 (2009; Addenda A 2012; R 2014) Connectors for Movable Gas Appliances

ANSI Z21.78/CSA 6.20 (2010; R 2015) Standard Specification for Combination Gas Controls for Gas Appliances

ANSI Z21.80/CSA 6.22 (2011; Addenda A 2012; R 2016) Line Pressure Regulators

AMERICAN PETROLEUM INSTITUTE (API)

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 (2014; Errata 1-2 2014; Errata 3-6 2015; ADD 1 2015; ADD 2 2016; Errata 7-8 2016; Errata 9 2017) Specification for Pipeline and Piping Valves

API Std 598 (2009) Valve Inspecting and Testing

API Std 607 (2016) Testing of Valves: Fire Test for Soft-Seated Quarter-Turn Valves

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

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME A13.1 (2023) Scheme for the Identification of Piping Systems

ASME B1.1 (2003; R 2008) 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) 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 B31.9 (2014) Building Services Piping

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

ASTM INTERNATIONAL (ASTM)

ASTM 01.01 (2016) Steel - Piping, Tubing, Fittings

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	(2017) Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM A513/A513M	(2020a) Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing
CSA GROUP (CSA)	
ANSI LC 1/CSA 6.26	(2016) Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing (CSST)
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	(2021) National Fuel Gas Code
NFPA 70	(2023; ERTA 7 2023; TIA 23-15) National Electrical Code
SOCIETY FOR PROTECTIVE COATINGS (SSPC)	
SSPC SP 6/NACE No.3	(2007) Commercial Blast Cleaning
U.S. DEPARTMENT OF DEFENSE (DOD)	
MIL-STD-101	(2014; Rev C) Color Code for Pipelines and for Compressed Gas Cylinders
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 and accessories; 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" designation; submittals not having a "G" designation are for information only. Submittals with an "S" are for inclusion in the Sustainability Notebook, 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

Gas Equipment Connectors; G  
Gas Piping System; G  
Pipe Coating Materials; G  
Pressure Regulators; 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

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 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 for metal 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 with AWS A5.8/A5.8M, and AWS WHB-2.9.

### 1.5.2 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 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 Steel Tubing, Joints and Fittings

Provide steel tubing conforming to ASTM 01.01, and ASTM A513/A513M, with tubing joints made up with gas tubing fittings recommended by the tubing manufacturer.

### 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 Insulating Pipe Joints

#### 2.2.8.1 Insulating Joint Material

Provide insulating joint material between flanged or threaded metallic pipe systems where shown to control galvanic or electrical action.

#### 2.2.8.2 Threaded Pipe Joints

Provide threaded pipe joints of steel body nut type dielectric unions with insulating gaskets.

#### 2.2.8.3 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.

### 2.2.9 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.
- c. Provide flexible hose connectors for natural gas service as indicated on the drawings and as required to accommodate any thermal expansion, contraction or seismic movement of the natural gas piping system. Flexible hose connectors shall be capable of compensating for lateral movement and vibration. Conform to the requirements of Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT. Flexible connectors for natural gas service shall be 300 series stainless steel corrugated hose and braid. Flexible hose connector end fittings 2 inch and smaller shall be schedule 40 carbon steel MPT. End fitting 2-1/2 inch and larger shall be schedule 40 carbon steel beveled for welding. All flexible hose connectors for natural gas service shall be CSA/AGA certified for flammable gas service and have a minimum pressure rating of 150 psig at 70 degrees F.

## 2.3 VALVES

Provide shutoff or service isolation valves as indicated in the drawings 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 PIPE HANGERS AND SUPPORTS

Provide pipe hangers and supports conforming to MSS SP-58.

## 2.5 REGULATORS AND SHUTOFF VALVES

Provide regulators conforming to ANSI Z21.18/CSA 6.3 for appliances ANSI Z21.78/CSA 6.20 for combination gas controls for gas appliances, and ANSI Z21.80/CSA 6.22 for line pressure regulators. Provide shutoff valves conforming to ANSI Z21.15/CSA 9.1 for manually controlled gas shutoff valves and ANSI Z21.21/CSA 6.5 for automatic shutoff valves for gas appliances.

## 2.6 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 shall 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 shall extend through the nuts and may have reduced shanks of a diameter not less than the diameter at root of threads. Bolts shall have American Standard regular square or heavy hexagon heads; nuts shall be American Standard heavy semifinished hexagonal.

## 2.7 GASKETS

Fluorinated elastomer, compatible with flange faces.

## 2.8 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 meter set assembly.

#### 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 shall be clear and free of cutting burrs and defects in structure or threading and shall 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 Aboveground Metallic Piping Systems

##### 3.4.1.1 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 or commercial sand blasted conforming to SSPC SP 6/NACE No.3 and prime with ferrous metal primer or vinyl type wash coat. Finish primed surfaces with two coats of exterior oil paint or vinyl paint.

#### 3.4.1.2 Nonferrous Surfaces

Do not paint nonferrous surfaces.

### 3.5 INSTALLATION

Install the gas system in conformance with the manufacturer's recommendations and applicable provisions of NFPA 54, 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.

#### 3.5.1 Metallic Piping Installation

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.

#### 3.5.2 Metallic Tubing Installation

Install metallic tubing using gas tubing fittings approved by the tubing manufacturer. CSST gas piping systems shall 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.

#### 3.5.3 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.

##### 3.5.3.1 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.

#### 3.5.4 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.

### 3.5.5 Final Gas Connections

Unless otherwise specified, make final connections with rigid metallic pipe and fittings. Make final connections to kitchen ranges using flexible connectors not less than 40 inch long and to permit movement of equipment for cleaning. Flexible connectors may be used for final connections to residential dryers. 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.

### 3.6 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.

### 3.7 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 FIRESTOPPING. Firestopping materials be furnished and installed by the Firestopping installer and shall conform to the requirements in Section 07 84 00 FIRESTOPPING.

### 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. Firestopping materials be furnished and installed by the Firestopping installer and shall conform to the requirements in 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 which is electrically continuous and bonded to a grounding electrode as required by 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 PRESSURE REGULATOR

Facility gas pressure regulator and meter assembly provided by gas utility provider as indicated on the drawings.

### 3.17 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.

#### 3.17.1 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.

#### 3.17.2 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.

#### 3.17.3 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.

3.17.4 Labor, Materials and Equipment

Furnish all labor, materials and equipment necessary for conducting the testing and purging.

3.18 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 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.

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 DCAACP (Online) Directory of Certified Applied Air-Conditioning Products

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 (2017) Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

ASHRAE 62.1 (2022) Ventilation for Acceptable Indoor Air Quality

ASHRAE 68 (1997) Laboratory Method of Testing to Determine the Sound Power In a Duct

ASHRAE 70 (2023) Method of Testing the Performance of Air Outlets and Inlets

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

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME A13.1 (2023) Scheme for the Identification of Piping Systems

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M (2022) 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	(2023) Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
ASTM B766	(2023) 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 ICS 6 (1993; R 2016) Industrial Control and  
Systems: Enclosures

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

NFPA 90A (2021) 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 1403 (2008) Accepted Industry Practice for  
Industrial Duct Construction, 2nd Edition

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" or "S" classification. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. 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

Constant Volume, Single Duct Terminal Units; G

Variable Volume, Single Duct Terminal Units; G

Variable Volume, Single Duct, Fan-Powered Terminal Units; G

Dual Duct Terminal Units; G

Ceiling Induction Terminal Units; G

Reheat Units; 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

Constant Volume, Single Duct Terminal Units; G

Variable Volume, Single Duct Terminal Units; G

Variable Volume, Single Duct, Fan-Powered Terminal Units; G

Dual Duct Terminal Units; G

Ceiling Induction Terminal Units; G

Reheat Units; 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>. Equipment having a lower efficiency may be specified if the designer determines such equipment to be more life-cycle cost effective.

#### 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. Provide written certification from the bolt manufacturer that the bolts furnished comply with the requirements of this specification. Include illustrations of product markings, and the number of each type of bolt to be furnished in the certification.

#### 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.

### 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. Paint in accordance with Section 09 96 00 HIGH-PERFORMANCE COATINGS.

## 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 A. 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-retardent 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 curtain type with damper blades 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 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 automatically operated inlet vanes on suction inlets. Provide automatically operated outlet dampers. Unless otherwise indicated, provide motors that do not exceed 1800 rpm and have dripproof enclosures. Provide magnetic 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 and outlet flanges, and automatic 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 disconnect switch, 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 disconnect switch, and extended base. 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 0.016 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 testcoils 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 with an extended surface pleated panel filter as a prefilter 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 with an extended surface pleated media panel filter as a prefilter in a factory preassembled side access housing, or a factory-made sectional frame bank, as indicated.

#### 2.10.3.4 Sectional Cleanable Filters

Provide 1 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 viscous adhesive 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 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 stainless 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 graduated in 0.01 inch of water, 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 taps 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 Field-Fabricated Air Handling Units

Provide built-up units as specified in paragraph DUCT SYSTEMS. Provide fans, coils spray-coil dehumidifiers, and air filters as specified in paragraph AIR SYSTEMS EQUIPMENT for types indicated.

### 2.11.2 Factory-Fabricated Air Handling Units

Provide single-zone draw-through type units as indicated. Units must include fans, coils, airtight insulated casing, adjustable V-belt drives, belt guards for externally mounted motors, access sections where indicated, 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.

#### 2.11.2.1 Casings

Provide the following:

- a. Casing sections 2 inch double wall type, constructed of a minimum 18 gauge galvanized steel, or 18 gauge 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.

#### 2.11.2.2 Heating and Cooling Coils

Provide coils as specified in paragraph AIR SYSTEMS EQUIPMENT.

#### 2.11.2.3 Air Filters

Provide air filters as specified in paragraph AIR SYSTEMS EQUIPMENT for types and thickness indicated.

#### 2.11.2.4 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. Motor sheaves that are variable pitch for 25 hp and below and fixed pitch above 25 hp as defined by AHRI Guideline 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.

#### 2.11.2.5 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.

#### 2.11.2.6 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 valve and piping package, 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 adjustable 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. 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 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.

2.12.2.1 Constant Volume, Single Duct Terminal Units

Provide constant volume, single duct, terminal units that contain within the casing, a constant volume regulator. Provide volume regulators that control air delivery to within plus or minus 5 percent of specified air flow subjected to inlet pressure from 3/4 to 6 inch water gauge.

2.12.2.2 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.

#### 2.12.2.3 Variable Volume, Single Duct, Fan-Powered Terminal Units

Provide variable volume, single duct, fan-powered terminal units with a calibrated air volume sensing device, air valve or damper, actuator, fan and motor, and accessory relays. Provide units that control primary air volume to within plus or minus 5 percent of each air set point as determined by the thermostat with variations in inlet pressure from 3/4 to 6 inch water gauge. Provide unit fan that is centrifugal, direct-driven, double-inlet type with forward curved blades. Provide either single speed with speed controller or three-speed, permanently lubricated, permanent split-capacitor type fan motor. Isolate fan/motor assembly from the casing to minimize vibration transmission. Provide factory furnished fan control that is wired into the unit control system. Provide a factory-mounted pressure switch to operate the unit fan whenever pressure exists at the unit primary air inlet or when the control system fan operates.

#### 2.12.2.4 Dual Duct Terminal Units

Provide dual duct terminal units with hot and cold inlet valve or dampers that are controlled in unison by single or dual actuators. Provide actuator as specified in paragraph SUPPLEMENTAL COMPONENTS/SERVICES, subparagraph CONTROLS. Provide unit that controls delivered air volumes within plus or minus 5 percent with inlet air variations from 1 to 8 inch water gauge in either duct. Include mixing baffles with the unit casing. Provide cabinet and closed duct leakage that does not exceed 2 percent of maximum rated air volume. Provide units with an internal resistance that does not exceed inch water gauge at maximum flow range.

#### 2.12.2.5 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 closed upon loss of pneumatic pressure. Factory pipe actuator and accuracy controls requiring only field installation of 20 psi pneumatic main air and room thermostat.

#### 2.12.2.6 Series Fan Powered Variable Air Volume (VAV) Terminals

Provide units factory assembled, designed, tested, rated in accordance with AHRI 880 I-P, that are AHRI certified, listed in the AHRI DCAACP and that produce a supply air discharge mix by modulation of conditioned primary air and recirculating of return air. Provide units that include

casing, centrifugal fan and motor, primary VAV damper or valve, electronic volume regulator, discharge air damper, primary air inlet cone with high and low pressure flow sensors, recirculating air filter frames, filter, and electrical disconnect. Provide hot water heating coils integral to the terminal, or provide insulated hot water coil section attached to the discharge of the terminal.

#### 2.12.2.6.1 Casing

Provide removable full bottom access panels for servicing internal components without disturbing duct connections. Insulate inside of casing with manufacturer's standard insulation. Provide units that have recirculating air inlet equipped with filter frame, round primary damper or valve, and unit mounting brackets.

#### 2.12.2.6.2 Fans and Motors

Provide centrifugal, forward curved, multiblade, fan wheels with direct-drive motors. Provide motors that are the high efficiency permanent-split capacitor type with thermal overload protection, permanently lubricated bearings, and have three speeds or are equipped with solid state speed controllers. Provide isolation between fan motor assembly and unit casing. Provide fan and motor that is removable through casing access panel.

#### 2.12.2.6.3 Flow Sensor

Provide ring or cross type sensor with minimum of two pickup points which average the velocity across the inlet. Obtain flow measurement within plus or minus 5 percent of rated airflow with 1.5 diameters of straight duct upstream of unit and inlet static variation of 0.5 to 5.0 inches water gauge. Supply flow measuring taps and calibration flowchart with each unit for field balancing airflows.

#### 2.12.2.6.4 Primary VAV Damper or Valve

Provide galvanized steel damper blade that closes against gasket inside unit. Connect damper to operating shaft with a positive mechanical connection. Provide nylon bearing for damper shaft. Cylindrical die cast aluminum valve inlet tapered to fit round flexible ducts with integral flow diffuser and beveled self-centering disc. Provide damper or valve leakage at shutoff that does not exceed 2 percent of capacity at 1 inch water gauge pressure.

#### 2.12.2.6.5 Regulator

Provide electronic volume regulator. Electronic controls contained in NEMA ICS 6, Type 1 enclosure sealed from airflow. Provide unit with controls mounted on side or on air valve. System powered regulators are not permitted. Provide volume regulator that resets primary air volume as determined by thermostat, within upstream static pressure variation noted in paragraph titled "Flow Sensor." Provide volume regulators that are field adjustable, factory set and calibrated to indicated maximum and minimum primary airflows, direct acting and normally open upon loss of pneumatic pressure.

#### 2.12.2.6.6 Electrical

Provide unit that incorporates single point electrical connection with

electrical disconnect. Provide electrical components that are UL or ETL listed, installed in accordance with NFPA 70 and mounted in control box. Units UL or ETL listed as an assembly do not require airflow switch interlock with electric heating coil, when factory assembled.

#### 2.12.2.6.7 Filters

Provide UL listed throwaway one inch thick fiberglass filters, standard dust-holding capacity.

#### 2.12.2.7 Reheat Units

##### 2.12.2.7.1 Hot Water Coils

Provide fin-and-tube type hot-water coils constructed of seamless copper tubes and copper or aluminum fins mechanically bonded or soldered to the tubes. Provide headers that are constructed of cast iron, welded steel or copper. Provide casing and tube support sheets that are 16 gauge, galvanized steel, formed to provide structural strength. Provide tubes that are correctly circuited for proper water velocity without excessive pressure drop and are drainable where required or indicated. At the factory, test each coil at not less than 250 psi air pressure and provide coils suitable for 200 psi working pressure. Install drainable coils in the air handling units with a pitch of not less than 1/8 inch per foot of tube length toward the drain end. Coils must conform to the provisions of AHRI 410.

##### 2.12.2.7.2 Steam Coils

Provide steam coils constructed of cast semisteel, welded steel, or copper headers, red-brass or copper tubes, and copper or aluminum fins mechanically bonded or soldered to the tubes. Roll and bush, braze or weld tubes into headers. Provide coil casings and tube support sheets, with collars of ample width, that are not lighter than 16 gauge galvanized steel formed to provide structural strength. When required, furnish multiple tube supports to prevent tube sag. Float the fin tube and header section within the casing to allow free expansion of tubing for coils subject to high pressure steam service. Provide coils that are factory pressure tested and capable of withstanding 250 psi hydrostatic test pressure or 250 psi air pressure, and are for 100 psi steam working pressure. Provide steam-distribution tube type preheat coils with condensing tubes having not less than 5/8 inch outside diameters. Provide distribution tubes that have not less than 3/8 inch outside diameter, with orifices to discharge steam to condensing tubes. Install distribution tubes concentric inside of condensing tubes held securely in alignment. Limit the maximum length of a single coil to 120 times the diameter of the outside tube. Other heating coils must be single tube type with an outside diameter not less than 1/2 inch. Provide supply headers that distribute steam evenly to all tubes at the indicated steam pressure. Provide coils that conform to the provisions of AHRI 410.

##### 2.12.2.7.3 Electric Resistance Heaters

Provide the duct-mounting type electric resistance heaters consisting of a nickel-chromium resistor mounted on refractory material and a steel or aluminum frame for attachment to ductwork. Provide electric duct heater that meets the requirement of Underwriters Laboratories and NFPA 70 and is provided with a built-in or surface-mounted high-limit thermostat. Interlock electric duct heaters electrically so that they cannot be



energized unless the fan is running.

## 2.13 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.

## 2.14 SUPPLEMENTAL COMPONENTS/SERVICES

### 2.14.1 Chilled, Condenser, or Dual Service Water Piping

The requirements for chilled, condenser, or dual service water piping and accessories are specified in Section 23 64 26 CHILLED, CHILLED-HOT, AND CONDENSER WATER PIPING SYSTEMS

### 2.14.2 Water or Steam Heating System Accessories

The requirements for water or steam heating accessories such as expansion tanks and steam traps are specified in Section 23 52 00 HEATING BOILERS.

### 2.14.3 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.

### 2.14.4 Backflow Preventers

The requirements for backflow preventers are specified in Section 22 00 00 PLUMBING, GENERAL PURPOSE.

### 2.14.5 Insulation

The requirements for shop and field applied insulation are specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

### 2.14.6 Controls

The requirements for controls are specified in Section 23 05 93 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS and Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

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.

### 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.

### 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 epoxy wash primer coating on exterior surfaces.

### 3.2.6 FRP Ductwork

Provide fibrous glass reinforced plastic ducting and related structures that conform to SMACNA 1403. Provide flanged joints where indicated. Crevice-free butt lay-up joints are acceptable where flanged joints are not indicated. When ambient temperatures are lower than 50 degrees F, heat cure joints by exothermic reaction heat packs.

### 3.2.7 Kitchen Exhaust Ductwork

#### 3.2.7.1 Ducts Conveying Smoke and Grease Laden Vapors

Provide ducts conveying smoke and grease laden vapors that conform to requirements of NFPA 96. Make seams, joints, penetrations, and duct-to-hood connections with a liquid tight continuous external weld. Provide duct material that is a minimum 18 gauge, Type 304L or 316L, stainless steel . Include with duct construction an external perimeter angle sized in accordance with SMACNA 1966, except place welded joint reinforcement on maximum of 24 inch centers; continuously welded companion angle bolted flanged joints with flexible ceramic cloth gaskets where indicated; pitched to drain at low points; welded pipe coupling-plug drains at low points; welded fire protection and detergent cleaning penetration; steel framed, stud bolted, and flexible ceramic cloth gasketed cleaning access provisions where indicated. Make angles, pipe couplings, frames, bolts, etc., the same material as that specified for the duct unless indicated otherwise.

#### 3.2.7.2 Exposed Ductwork

Provide exposed ductwork that is fabricated from minimum 18 gauge, Type 304L or 316L, stainless steel with continuously welded joints and seams. Pitch ducts to drain at hoods and low points indicated. Match surface finish to hoods.

#### 3.2.7.3 Concealed Ducts Conveying Moisture Laden Air

Fabricate concealed ducts conveying moisture laden air from minimum 18 gauge, Type 300 series, stainless steel . Continuously weld, braze, or solder joints to be liquid tight. Pitch ducts to drain at points indicated. Make transitions to other metals liquid tight, companion angle bolted and gasketed.

### 3.2.8 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.

### 3.2.9 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.

### 3.2.10 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.

### 3.2.11 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.

### 3.2.12 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.

### 3.2.13 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 28 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 room fan-coil 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 RADIANT PANELS

#### 3.14.1 Installation

Install radiant panels level and plumb, maintaining sufficient clearance for normal services and maintenance.

#### 3.14.2 Soldering

When soldering copper fittings at the panel, a heat pad will be used to protect the panel finish.

#### 3.14.3 Connections

Install piping adjacent to radiant panels to allow for service and maintenance.

### 3.15 OPERATION AND MAINTENANCE

#### 3.15.1 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

#### 3.15.2 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 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 52 00

HEATING BOILERS  
04/08

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 801 (2001; R 2008) Industrial Process/Power  
Generation Fans: Specification Guidelines

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI Z21.13/CSA 4.9 (2014; Errata 2014) Gas-Fired Low Pressure  
Steam and Hot Water Boilers

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

ASHRAE 52.2 (2017) Method of Testing General  
Ventilation Air-Cleaning Devices for  
Removal Efficiency by Particle Size

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C606 (2015) Grooved and Shouldered Joints

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

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

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

ASME B16.11 (2016) Forged Fittings, Socket-Welding and  
Threaded

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 B16.20 (2012) Metallic Gaskets for Pipe Flanges -

	Ring-Joint, Spiral Wound, and Jacketed
ASME B16.22	(2021) Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B16.26	(2013) Standard for Cast Copper Alloy Fittings for Flared Copper Tubes
ASME B16.3	(2021) Malleable Iron Threaded Fittings, Classes 150 and 300
ASME B16.34	(2021) Valves - Flanged, Threaded and Welding End
ASME B16.39	(2014) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, 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 B16.9	(2012) Standard for Factory-Made Wrought Steel Buttwelding Fittings
ASME B31.1	(2022) Power Piping
ASME B31.5	(2016) Refrigeration Piping and Heat Transfer Components
ASME B40.100	(2013) Pressure Gauges and Gauge Attachments
ASME BPVC SEC IV	(2017) BPVC Section IV-Rules for Construction of Heating Boilers
ASME BPVC SEC VIII D1	(2019) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1
ASME CSD-1	(2016) Control and Safety Devices for Automatically Fired Boilers

ASTM INTERNATIONAL (ASTM)

ASTM A105/A105M	(2021) Standard Specification for Carbon Steel Forgings for Piping Applications
ASTM A193/A193M	(2023) Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service and Other Special Purpose Applications
ASTM A234/A234M	(2016) Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service

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 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 B32 (2020) Standard Specification for Solder Metal

ASTM B62 (2015) Standard Specification for Composition Bronze or Ounce Metal Castings

ASTM B75/B75M (2011) Standard Specification for Seamless Copper Tube

ASTM B813 (2016) Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube

ASTM B828 (2016) Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings

ASTM B88 (2016) Standard Specification for Seamless Copper Water Tube

ASTM D1784 (2011) Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

COPPER DEVELOPMENT ASSOCIATION (CDA)

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

HYDRONICS INSTITUTE DIVISION OF AHRI (HYI)

HI-004 (1995) Radiant Floor Heating

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

MSS SP-110 (2010) Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends

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-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	(2013) Bronze Gate, Globe, Angle and Check Valves
MSS SP-85	(2011) Gray Iron Globe & Angle Valves Flanged and Threaded Ends

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA MG 1	(2021) Motors and Generators

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 54	(2021) National Fuel Gas Code
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UNDERWRITERS LABORATORIES (UL)

UL 1738	(2010; Reprint Nov 2014) Venting Systems for Gas-Burning Appliances, Categories II, III and IV
UL FLAMMABLE & COMBUSTIBLE	(2012) Flammable and Combustible Liquids and Gases Equipment Directory

1.2 RELATED REQUIREMENTS

Section 25 05 11.01 CYBERSECURITY FOR LOW IMPACT HVAC CONTROL SYSTEMS  
applies to this section with additions and modifications specified herein.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation;  
submittals not having a "G" designation are for information only.  
Submittals with an "S" are for inclusion in the Sustainability Notebook,  
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

Materials and Equipment; G

Spare Parts; G

Water Treatment System; G

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1.4 QUALITY ASSURANCE

Submit a copy of qualified welding procedures and a list of names and identification symbols of qualified welders and welding operators, at least 2 weeks prior to the start of welding operations.

1.5 DELIVERY, STORAGE, AND HANDLING

Protect equipment delivered and placed in storage from the weather, humidity and temperature variations, dirt and dust, and other contaminants.

1.6 EXTRA MATERIALS

Submit spare parts data for each different item of material and equipment

specified, after approval of the detail drawings and no 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, and a list of the parts recommended by the manufacturer to be replaced after 1 and 3 years of service.

## PART 2 PRODUCTS

### 2.1 MATERIALS AND EQUIPMENT

#### 2.1.1 Standard Products

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. Equipment shall be supported by a service organization that is, in the opinion of the Contracting Officer, reasonably convenient to the site. Submit manufacturer's catalog data included with the detail drawings for the following:

- a. Data showing model, size, options, etc., that are intended for consideration. Data submitted shall be adequate to demonstrate compliance with contract requirements. Data shall include manufacturer's written installation instructions and manufacturer's recommendations for operation and maintenance clearances for the following:

- (1) Boilers
- (2) Unit Heaters
- (3) Fuel Burning Equipment
- (4) Combustion Control Equipment
- (5) Pumps
- (6) Fittings and Accessories
- (7) Water Treatment System
- (8) Domestic Hot Water Heat Exchanger

#### 2.1.2 Asbestos Prohibition

Asbestos and asbestos-containing products will not be allowed.

#### 2.1.3 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, display an ENERGY STAR labels as applicable. Each pressure vessel shall have an approved ASME stamp.

#### 2.1.4 Equipment Guards

Belts, pulleys, chains, gears, couplings, projecting setscrews, keys, and other rotating parts exposed to personnel contact shall be fully enclosed or guarded in accordance with OSHA requirements. High temperature equipment and piping exposed to contact by personnel or where it creates a potential fire hazard shall be properly guarded or covered with insulation of a type specified. Catwalks, operating platforms, ladders, and guardrails shall be provided where shown and shall be constructed in accordance with Section 05 50 13 MISCELLANEOUS METAL FABRICATIONS05 51 33 METAL LADDERS.

## 2.2 BOILERS

Each boiler shall have the output capacity in British thermal units per hour (Btuh) as indicated when fired with the specified fuels. The boiler shall be furnished complete with the gas burning equipment, boiler fittings and trim, automatic controls, forced draft fan, electrical wiring, insulation, piping connections, and protective jacket. The boiler shall be completely assembled and boiler burner fired and tested at the manufacturer's plant. Boiler manufacturer shall submit boiler test report for each boiler. Boiler auxiliaries including fans, motors, drives, and similar equipment shall be provided with at least 10 percent excess capacity to allow for field variations in settings and to compensate for any unforeseen increases in pressure losses in appurtenant piping and ductwork. However, the boiler safety devices shall not be sized for a 10 percent excess capacity. The boiler and its accessories shall be designed and installed to permit ready accessibility for operation, maintenance, and service. Boilers shall be designed, constructed, and equipped in accordance with ASME BPVC SEC IV. Each boiler shall be of the condensing type and designed for water service as specified herein.

### 2.2.1 Condensing Boiler

Each boiler shall be a self-contained packaged type, complete with accessories, mounted on a structural steel base or a steel base which is integral to the boiler shell. Each boiler shall conform to the commercial design used by the manufacturer and shall permit free thermal expansion without placing undue stress on any part of the boiler. Each boiler which experiences the formation of condensate within the flue gas shall be specifically designed for condensing application. Each boiler shall withstand the corrosive effects of condensate for each part which may be in contact with the condensate at all possible operating conditions. Each boiler shall be provided with a separate air intake, exhaust, and condensate drain. Each boiler shall be designed to withstand the water temperature differentials anticipated at the required operating conditions without experiencing any damage due to thermal shock.

### 2.2.2 Hot Water Heating Boilers

The hot water heating boiler shall be capable of operating at the specified maximum continuous capacity without damage or deterioration to the boiler, its setting, firing equipment, or auxiliaries. The rated capacity shall be the capacity at which the boiler will operate continuously while maintaining at least the specified minimum efficiency. The boiler design conditions shall be as shown on the drawings.

## 2.3 FUEL BURNING EQUIPMENT

Boiler shall be designed to burn natural gas. Each boiler shall comply with Federal, state, and local emission regulations.

### 2.3.1 Burners

#### 2.3.1.1 Gas Fired Burners and Controls

Burners shall be UL approved mechanical draft burners with all air necessary for combustion supplied by a blower where the operation is coordinated with the burner. Burner shall be provided complete with fuel supply system in conformance with the following safety codes or standards:



- a. Gas fired units less than 12,500,000 BTU input shall conform to ANSI Z21.13/CSA 4.9. Gas fired units less than 12,500,000 Btuh input shall conform to ASME CSD-1.

### 2.3.2 Draft Fans

Fans conforming to AMCA 801 forced-draft shall be furnished as an integral part of boiler design. Fans shall be centrifugal with backward-curved blades or axial flow type. Each fan shall be sized for output volume and static pressure rating sufficient for pressure losses, excess air requirements at the burner, leakages, temperature, and elevation corrections for worst ambient conditions, all at full combustion to meet net-rated output at normal firing conditions, plus an overall excess air volume of 10 percent against a 20 percent static overpressure. Sound pressure levels for fans shall not exceed 85 decibels in any octave band at a 3 foot station. Forced draft fan bearings shall be air cooled.

#### 2.3.2.1 Draft Fan Control

Forced-draft centrifugal fans shall have inlet vane controls or shall have variable speed control where indicated. Inlet vanes shall be suitable for use with combustion control equipment.

#### 2.3.2.2 Draft Fan Drives

Fans shall be driven by electric motors. Electric motor shall be drip proof. Motor starter shall be magnetic across-the-line type with general purpose enclosure and shall be furnished with not less than two auxiliary interlock contacts.

### 2.3.3 Draft Damper

Boilers shall be provided with manual, automatic dampers, draft hoods, or barometric dampers as recommended by the boiler manufacturer to maintain proper draft in the boiler. Draft damper shall be provided in a convenient and accessible location in the flue gas outlet from the boiler. Automatic damper shall be arranged for automatic operation by means of a damper regulator.

### 2.3.4 Ductwork

Air ducts connecting the forced-draft fan units with the plenum chamber shall be designed to convey air with a minimum of pressure loss due to friction. Ductwork shall be galvanized sheet metal conforming to ASTM A653/A653M. Ducts shall be straight and smooth on the inside with laps made in direction of air flow. Ducts shall have cross-break with enough center height to assure rigidity in the duct section, shall be angle iron braced, and shall be completely free of vibration. Access and inspection doors shall be provided as indicated and required, with a minimum of one in each section between dampers or items of equipment. Ducts shall be constructed with long radius elbows having a centerline radius 1-1/2 times the duct width, or where the space does not permit the use of long radius elbows, short radius or square elbows with factory-fabricated turning vanes may be used. Duct joints shall be substantially airtight and shall have adequate strength for the service, with 1-1/2 x 1-1/2 x 1/8 inch angles used where required for strength or rigidity. Duct wall thickness shall be 16 gauge (0.0598 inch) for ducts 60 inches or less and 12 gauge (0.1046 inch) for ducts larger than 60 inches in maximum dimension. Additional ductwork shall be in accordance

with Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM.

#### 2.4 COMBUSTION CONTROL EQUIPMENT

Combustion control equipment shall be provided as an integral part of the packaged boiler. The boiler water temperature shall be controlled by a water temperature controller. The equipment shall operate electronically. On multiple boiler installations, each boiler unit shall have a completely independent system of controls responding to the load.

##### 2.4.1 Electrical controls

Electrical control devices shall be rated at 24 volts and shall be connected as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

##### 2.4.2 Water Temperature Controller

The controller shall be of sturdy construction and shall be protected against dust and dampness. The thermostatic element shall be inserted in a separable socket installed in the upper part of the boiler near the water outlet. Controller shall be furnished with necessary equipment to automatically adjust the setting to suit the outside weather conditions. The outside air reset controller shall be operated in such a manner that the operating temperatures required by the boiler manufacturer are not compromised.

##### 2.4.3 Boiler Combustion Controls

- a. Gas fired boiler units shall be provided with modulating combustion controls with gas pilot or spark ignition. Modulating controls shall be provided with a means for manually controlling the firing rate.
- b. Modulating control function shall be accomplished using modulating gas valve and variable speed or inlet guide vane combustion air fan responding to a water temperature controller. Combustion control equipment shall include draft controls with synchronized fuel feed and combustion air supply controls and shall maintain the proper air/fuel ratio. The desired furnace draft shall be maintained within 0.01 inch of water column.

##### 2.4.4 Combustion Safety Controls and Equipment

Combustion safety controls and equipment shall be UL listed, microprocessor-based distributed process controller. The system shall include mounting hardware, wiring and cables, and associated equipment. The controller shall be mounted completely wired, programmed, debugged, and tested to perform all of its functions. The controller shall process the signals for complete control and monitoring of the boiler. This shall include maintaining boiler status, starting and stopping all control functions, sequencing control functions and signaling alarm conditions. The program shall be documented and include cross references in description of coils and contacts. Microprocessor shall be able to perform self diagnostics and contain a message center to provide operator with status and failure mode information. Controllers for each boiler shall be mounted on the boiler supporting structure or integral to the boiler. Control systems and safety devices for automatically fired boilers shall conform to ASME CSD-1. Electrical combustion and safety controls shall be rated at 120 volts, single phase, 60 Hz and shall be

connected as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. A 4 inch diameter alarm bell shall be provided and shall be located on or adjacent to the boiler. The alarm bell shall ring when the boiler is shut down by any safety control or interlock. Indicating lights shall be provided on the control panel. A red light shall indicate flame failure, and a green light shall indicate that the main fuel valve is open. The following shutdown conditions shall require a manual reset before the boiler can automatically recycle:

- a. Flame failure.
- b. Failure to establish pilot flame.
- c. Failure to establish main flame.
- d. Low-water cutoff.
- e. High temperature cutoff.

#### 2.4.4.1 Low-water Cutoff

Low water cutoff shall be float actuated switch or electrically actuated probe type low-water cutoff. Float chamber shall be provided with a blow-down connection. Cutoff shall cause a safety shutdown and sound an alarm when the boiler water level drops below a safe minimum level. A safety shutdown due to low water shall require manual reset before operation can be resumed and shall prevent recycling of the burner. The cutoff shall be in strict accordance to ASME CSD-1.

#### 2.4.4.2 Water Flow Interlock

Hot water boiler limit controls shall be provided to include protection for low boiler water flow and high boiler water temperature. The limit controls shall be interlocked with the combustion control system to effect boiler alarm and shutdown. The controls shall not allow boiler startup unless hot water flow is proven.

### 2.5 PUMPS

#### 2.5.1 Heating Water Pumps

Pumps for heating water shall be the vertical, split coupled, in-line electrically driven single-stage centrifugal type and have a capacity not less than indicated. The pump shaft shall be constructed of corrosion-resistant alloy steel, sleeve bearings and glands of bronze designed to accommodate a mechanical seal, and the housing of close-grained cast iron. Pump seals shall be capable of withstanding 240 degrees F temperature without external cooling. The motor shall have sufficient power for the service required, shall be NEMA premium efficiency with Class F insulation rated for inverter duty, shall be suitable for the available electric service, and shall conform to the requirements of paragraph ELECTRICAL EQUIPMENT. Pump/motor shall be provided with a packaged variable frequency drive (VFD) conforming to the requirements of Section 26 29 23, ADJUSTABLE SPEED DRIVE (ASD) SYSTEMS UNDER 600 VOLTS. In addition, the heating water pump variable frequency drives or ECM shall be configured to vary the output frequency based on a differential pressure signal from a remote differential pressure transmitter or utilize software resident in the VFD/ECM to provide automatic pump speed control without the need for a pump mounted or remote

mounted differential pressure transmitter. Each pump suction and discharge connection shall be provided with a pressure gauge as specified.

## 2.6 COLD WATER CONNECTIONS

Connections shall be provided which includes consecutively in line a strainer, reduced pressure principle backflow preventers, and water pressure regulator in that order in the direction of the flow. The reduced pressure principle backflow preventers shall be provided as indicated and in compliance with Section 22 00 00 PLUMBING, GENERAL PURPOSE. Cold water fill connections shall be made to the water supply system as indicated. Necessary pipe, fittings, and valves required for water connections between the boiler and cold water main shall be provided as shown. The pressure regulating valve shall be of a type that will not stick or allow pressure to build up on the low side. The valve shall be set to maintain a terminal pressure of approximately 5 psi in excess of the static head on the system and shall operate within a 2 psi tolerance regardless of cold water supply piping pressure and without objectionable noise under any condition of operation.

## 2.7 DOMESTIC HOT WATER HEAT EXCHANGER

Domestic hot water heat exchangers shall include double wall brazed plate heat exchanger with domestic water and boiler water inlet and outlet fittings.

### 2.7.1 Brazed Plate Heat Exchanger

Brazed plate heat exchanger shall be double wall design, counterflow with AISI 316 stainless steel plates and copper brazing. Heat exchanger shall be designed and manufactured in accordance with ASME Code Section VIII, Division 1 for 435 PSIG at 450 degrees F. Domestic water side shall be rated for not less than 435 PSIG and boiler water side shall be rated at not less than 435 PSIG at 450 degrees F. Brazed plate heat exchanger shall be atmospherically vented and furnished with visible leak detection ports.

### 2.7.2 Domestic Hot and Cold Water Piping and Accessories:

Refer to SECTION 22 00 00, PLUMBING, GENERAL PURPOSE.

## 2.8 UNIT HEATERS

Heaters shall be as specified below, and shall have a heating capacity not in excess of 125 percent of the capacity indicated.

### 2.8.1 Propeller Fan Heaters

Heaters shall be designed for suspension and arranged for horizontal discharge of air as indicated. Casings shall be not less than 20 gauge black steel and finished with lacquer or enamel. Suitable adjustable air deflectors shall be provided to assure proper air and heat penetration capacity at floor level based on established design temperature. Suspension from heating pipes will not be permitted. Horizontal discharge type unit heaters shall have discharge or face velocities not in excess of the following:

Unit Capacity, cfm	Face Velocity, fpm
Up to 1000	800
1,001 to 3,000	900
3001 and over	1,000

#### 2.8.2 Centrifugal Fan Heaters

Heaters shall be arranged for floor mounting as indicated. Heating elements and fans shall be housed in steel cabinets of sectionalized steel plates or reinforced with angle-iron frames. Cabinets shall be constructed of not lighter than xxxx gauge black steel. Each unit heater shall be provided with a means of diffusing and distributing the air. Fans shall be mounted on a common shaft, with one fan to each air outlet. Fan shaft shall be equipped with self-aligning ball, roller, or sleeve bearings and accessible means of lubrication. Fan shaft may be either directly connected to the driving motor or indirectly connected by adjustable V-belt drive rated at 150 percent of motor capacity. All fans in any one unit heater shall be the same size.

#### 2.8.3 Heating Elements

Heating coils and radiating fins shall be of suitable nonferrous alloy with threaded fittings at each end for connecting to external piping. The heating elements shall be free to expand or contract without developing leaks and shall be properly pitched for drainage. The elements shall be tested under a hydrostatic pressure of 200 psig and a certified report of the test shall be submitted to the Contracting Officer. Coils shall be suitable for use with water up to 250 degrees F.

#### 2.8.4 Motors

Motors shall be provided with NEMA 250 general purpose enclosure. Motors and motor controls shall otherwise be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

#### 2.8.5 Motor Switches

Motors shall be provided with manual selection switches with "Off," and "Automatic" positions and shall be equipped with thermal overload protection.

#### 2.8.6 Controls

Controls shall be provided as specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

#### 2.9 AIR HANDLING UNITS

Air handling units and associated equipment shall be in accordance with Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM.

#### 2.10 FITTINGS AND ACCESSORIES

Boiler fittings and accessories shall be installed with each boiler in accordance with ASME BPVC SEC IV, unless otherwise specified.

### 2.10.1 Direct Vents

Direct venting shall be used for condensing type boilers. Both the air intake and exhaust vents shall be sized and located as indicated on the drawings and as recommended by the boiler manufacturer. A separate combustion air intake vent and exhaust vent shall be provided for each boiler.

#### 2.10.1.1 Combustion Air Intake Vent

The combustion air intake piping shall be constructed of Schedule 40 PVC in accordance with ASTM D1784. The vent shall be suitable for the temperature at the boiler combustion air intake connection point. Each intake shall be provided complete with bird screen.

#### 2.10.1.2 Exhaust Vent

The exhaust vent piping shall be constructed of AL29-4C double wall stainless steel conforming to UL 1738 and the boiler manufacturer's recommendations. Plastic materials polyetherimide (PEI) and polyethersulfone (PES) are forbidden to be used for vent piping of combustion gases. The exhaust vent shall be suitable for the maximum anticipated boiler exhaust temperature and shall withstand the corrosive effects of the condensate. A 0.3125 inch diameter hole shall be provided in the stack not greater than 6 inches from the boiler flue outlet for sampling of the exit gases. A method shall be provided to seal the hole to prevent exhaust gases from entering the boiler room when samples are not being taken. Each exhaust stack shall terminate with a rain cap suitable for use with the double wall flue vent having a free area of not less than the connected vent pipe. Provide minimum 1/2" mesh bird screen at the rain cap opening..

### 2.10.2 Expansion Tank

The hot water pressurization system shall include a bladder-type expansion tank which will accommodate the expanded water of the system generated within the normal operating temperature range, limiting the pressure increase at all components in the system to the maximum allowable pressure at those components. The sizes shall be as indicated. The expansion tank shall be welded steel, constructed, tested, and stamped in accordance with ASME BPVC SEC VIII D1 for a working pressure of 125 psi and precharged to the minimum operating pressure. The tank's air chamber shall be fitted with an air charging valve and pressure gauge. The tank shall be supported by steel legs or bases for vertical installation or steel saddles for horizontal installations. The tank shall have lifting rings and a drain connection. All components shall be suitable for a maximum operating temperature of 250 degrees F.

### 2.10.3 Air Separator

External air separation tank shall be steel, constructed, tested and stamped in accordance with ASME BPVC SEC VIII D1 for a working pressure of 125 psi. The capacity of the air separation tank indicated is minimum.

### 2.10.4 Filters

Filters shall conform to ASHRAE 52.2.

## 2.10.5 Steel Sheets

### 2.10.5.1 Galvanized Steel

Galvanized steel shall be ASTM A653/A653M.

### 2.10.5.2 Uncoated Steel

Uncoated steel shall be composition, condition, and finish best suited to the intended use.

## 2.10.6 Gaskets

Gaskets shall be nonasbestos material in accordance with ASME B16.20, full face or self-centering type. The gaskets shall be of the spiral wound type with graphite filler material.

## 2.10.7 Steel Pipe and Fittings

### 2.10.7.1 Steel Pipe

Steel pipe shall be ASTM A53/A53M, Type E or S, Grade A or B, black steel, standard weight.

### 2.10.7.2 Steel Pipe Fittings

Fittings shall have the manufacturer's trademark affixed in accordance with MSS SP-25 so as to permanently identify the manufacturer.

### 2.10.7.3 Steel Flanges

Flanged fittings including flanges, bolts, nuts, bolt patterns, etc. shall be in accordance with ASME B16.5 class 150 and shall have the manufacturer's trademark affixed in accordance with MSS SP-25. Flange material shall conform to ASTM A105/A105M. Flanges for high temperature water systems shall be serrated or raised-face type. Blind flange material shall conform to ASTM A516/A516M cold service and ASTM A515/A515M for hot service. Bolts shall 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 requirements of this specification. The certification shall include illustrations of product markings, the date of manufacture, and the number of each type of bolt to be furnished based on this certification.

### 2.10.7.4 Welded Fittings

Welded fittings shall conform to ASTM A234/A234M with WPA marking. Buttwelded fittings shall conform to ASME B16.9, and socket-welded fittings shall conform to ASME B16.11.

### 2.10.7.5 Cast-Iron Fittings

Fittings shall be ASME B16.4, Class 125, type required to match connecting piping.

### 2.10.7.6 Malleable-Iron Fittings

Fittings shall be ASME B16.3, type as required to match connecting piping.

#### 2.10.7.7 Unions

Unions shall be ASME B16.39, Class 150.

#### 2.10.7.8 Threads

Pipe threads shall conform to ASME B1.20.1.

#### 2.10.8 Copper Tubing and Fittings

##### 2.10.8.1 Copper Tubing

Tubing shall be ASTM B88, Type K or L. Adapters for copper tubing shall be brass or bronze for brazed fittings.

##### 2.10.8.2 Solder-Joint Pressure Fittings

Wrought copper and bronze solder-joint pressure fittings shall conform to ASME B16.22 and ASTM B75/B75M. Cast copper alloy solder-joint pressure fittings shall conform to ASME B16.18 and ASTM B828.

##### 2.10.8.3 Flared Fittings

Cast copper alloy fittings for flared copper tube shall conform to ASME B16.26 and ASTM B62.

##### 2.10.8.4 Adapters

Adapters may be used for connecting tubing to flanges and to threaded ends of valves and equipment. Extracted brazed tee joints produced with an acceptable tool and installed as recommended by the manufacturer may be used.

##### 2.10.8.5 Threaded Fittings

Cast bronze threaded fittings shall conform to ASME B16.15.

##### 2.10.8.6 Brazing Material

Brazing material shall conform to AWS A5.8/A5.8M.

##### 2.10.8.7 Brazing Flux

Flux shall be in paste or liquid form appropriate for use with brazing material. Flux shall be as follows: lead-free; have a 100 percent flushable residue; contain slightly acidic reagents; contain potassium borides, and contain fluorides. Silver brazing materials shall be in accordance with AWS A5.8/A5.8M.

##### 2.10.8.8 Solder Material

Solder metal shall conform to ASTM B32 95-5 tin-antimony.

##### 2.10.8.9 Solder Flux

Flux shall be either liquid or paste form, non-corrosive and conform to ASTM B813.



#### 2.10.9 Dielectric Waterways and Flanges

Dielectric waterways shall have temperature and pressure rating equal to or greater than that specified for the connecting piping. Waterways shall have metal connections on both ends suited to match connecting piping. Dielectric waterways shall be internally lined with an insulator specifically designed to prevent current flow between dissimilar metals. Dielectric flanges shall meet the performance requirements described herein for dielectric waterways.

#### 2.10.10 Flexible Pipe Connectors

Flexible pipe connectors shall be designed for 125 psi or 150 psi service. Connectors shall be installed where indicated. The flexible section shall be constructed of rubber, tetrafluoroethylene resin, or corrosion-resisting steel, bronze, monel, or galvanized steel. Materials used and the configuration shall be suitable for the pressure, vacuum, and temperature medium. The flexible section shall be suitable for service intended and may have threaded, welded, soldered, flanged, or socket ends. Flanged assemblies shall be equipped with limit bolts to restrict maximum travel to the manufacturer's standard limits. Unless otherwise indicated, the length of the flexible connectors shall be as recommended by the manufacturer for the service intended. Internal sleeves or liners, compatible with circulating medium, shall be provided when recommended by the manufacturer. Covers to protect the bellows shall be provided where indicated.

#### 2.10.11 Pipe Supports

Pipe supports shall conform to MSS SP-58.

#### 2.10.12 Pipe Expansion

##### 2.10.12.1 Packed Slip Tube Type Expansion Joints

Provide double packed slip tube expansion joints where indicated on the drawings. Expansion joints shall be designed for a fluid service of 150 psig at 230 degree F and a maximum 4" traverse. Joint shall be double slip design and furnished with an anchor base. The ends of the slip and body shall be furnished with 150 lb. raised face forged steel flanges. Stuffing box shall have integral internal and external guide surfaces. Guide surfaces shall have low friction, non-metallic inserts. Expansion joints shall have 2 inch minimum diameter packing cylinders welded in place to allow packing to be injected under full line pressure. The packing cylinder tip shall incorporate a check valve effect tip design to prevent the blow back of packing while adding packing to the expansion joint at full line pressure. Stuffing box and body shall be machined from A106 seamless pipe, schedule 80. All slips shall be machined and ground to achieve a 16 RMS finish before plating. Expansion joints shall be factory packed for the intended service with Flake Graphite injectable packing. Provide each packed slip tube type expansion joint with 1.5 inch thick two (2) piece removable reusable insulation blanket to cover the expansion joint body and slip. Blanket shall be configured to provide access to the packing cylinders without removal of the body portions of the insulation. The inner and outer covers shall be fabricated from Silicone Impregnated Nomex cloth with an Inconel wire mesh liner attached to the inner cover.

### 2.10.13 Valves

Valves shall be Class 125 and shall be suitable for the application. Grooved ends in accordance with AWWA C606 may be used for water service only. Valves in nonboiler external piping shall meet the material, fabrication and operating requirements of ASME B31.1. The connection type of all valves shall match the same type of connection required for the piping on which installed.

#### 2.10.13.1 Globe Valves

Globe valves 2-1/2 inches and smaller shall conform to MSS SP-80, bronze, threaded, soldered, or flanged ends. Globe valves 3 inches and larger shall conform to MSS SP-85, cast iron, bronze trim, flanged, or threaded ends.

#### 2.10.13.2 Check Valves

Check valves 2-1/2 inches and smaller shall conform to MSS SP-80, bronze, threaded, soldered, or flanged ends. Check valves 3 inches and larger shall conform to MSS SP-71, cast iron, bronze trim, flanged, or threaded ends.

#### 2.10.13.3 Ball Valves

Ball valves 1/2 inch and larger shall conform to MSS SP-72 or MSS SP-110, ductile iron or bronze, threaded, soldered, or flanged ends.

#### 2.10.13.4 Plug Valves

Plug valves 2 inch and larger shall conform to MSS SP-78. Plug valves smaller than 2 inch shall conform to ASME B16.34.

#### 2.10.13.5 Balancing Valves

Balancing valves shall have meter connections with positive shutoff valves. An integral pointer shall register the degree of valve opening. Valves shall be calibrated so that flow rate can be determined when valve opening in degrees and pressure differential across valve is known. Each balancing valve shall be constructed with internal seals to prevent leakage and shall be supplied with preformed insulation. Valves shall be suitable for 250 degrees F temperature and working pressure of the pipe in which installed. Valve bodies shall be provided with tapped openings and pipe extensions with shutoff valves outside of pipe insulation. The pipe extensions shall be provided with quick connecting hose fittings for a portable meter to measure the pressure differential. One portable differential meter shall be furnished. The meter suitable for the operating pressure specified shall be complete with hoses, vent, and shutoff valves, and carrying case. In lieu of the balancing valve with integral metering connections, a ball valve or plug valve with a separately installed orifice plate or venturi tube may be used for balancing.

#### 2.10.13.6 Drain valves

Drain valves shall be provided at each drain point of blowdown as recommended by the boiler manufacturer. Piping shall conform to ASME BPVC SEC IV and ASTM A53/A53M.

#### 2.10.13.7 Safety Valves

Safety valves shall have steel bodies and shall be equipped with corrosion-resistant trim and valve seats. The valves shall be properly guided and shall be positive closing so that no leakage can occur. Adjustment of the desired back-pressure shall cover the range between 2 and 10 psig. The adjustment shall be made externally, and any shafts extending through the valve body shall be provided with adjustable stuffing boxes having renewable packing. Boiler safety valves of proper size and of the required number, in accordance with ASME BPVC SEC IV, shall be installed so that the discharge will be through piping extended to a location as indicated. Each discharge pipe for hot water service shall be pitched away from the valve seat.

#### 2.10.13.8 Chainwheels

Chainwheel valve actuation assemblies shall include sprocket rim, chain guides, chain and attachment brackets for mounting chainwheels to hand wheels. Sprocket rim with chain guides shall be ductile or cast iron, or the type and size required for the valve. Include zinc or epoxy coating. Chain shall be hot-dip, galvanized steel, of the size required to fit the sprocket rim.

#### 2.10.14 Strainers

Basket and "Y" type strainers shall be the same size as the pipelines in which they are installed. The strainer bodies shall be heavy and durable, fabricated of cast iron, and shall have bottoms drilled and tapped with a gate valve attached for blowdown purposes. Strainers shall be designed for 125 psig service and 200 degrees F. The bodies shall have arrows clearly cast on the sides indicating the direction of flow. Each strainer shall be equipped with an easily removable cover and sediment screen. The screen shall be made of 22 gauge thick corrosion-resistant steel with small perforations numbering not less than 400/square inch to provide a net free area through the basket of at least 3.30 times that of the entering pipe. The flow shall be into the screen and out through the perforations.

#### 2.10.15 Pressure Gauges

Gauges shall conform to ASME B40.100 and shall be provided with throttling type needle valve or a pulsation dampener and shutoff valve. Minimum dial size shall be 3-1/2 inches. A pressure gauge shall be provided for each boiler in a visible location on the boiler. Pressure gauges shall be provided with readings in psi. Pressure gauges shall have an indicating pressure range that is related to the operating pressure of the fluid in accordance with the following table:

Operating Pressure (psi)	Pressure Range (psi)
76-150	0-200
16-75	0-100
2-15	0-30 (retard)

#### 2.10.16 Thermometers

Thermometers shall be provided with wells and separable corrosion-resistant steel sockets. Mercury shall not be used in thermometers. Thermometers for inlet water and outlet water for each hot water boiler shall be provided in a visible location on the boiler. Thermometers shall have brass, malleable iron, or aluminum alloy case and frame, clear protective face, permanently stabilized glass tube with indicating-fluid column, white face, black numbers, and a minimum 9 inch scale. The operating range of the thermometers shall be 32-212 degrees F. The thermometers shall be provided with readings in degrees F.

#### 2.10.17 Air Vents

##### 2.10.17.1 Manual Air Vents

Manual air vents shall be brass or bronze valves or cocks suitable for the pressure rating of the piping system and furnished with threaded plugs or caps.

##### 2.10.17.2 Automatic Air Vents

Automatic air vents shall be 3/4 inch quick-venting float and vacuum air valves. Each air vent valve shall have a large port permitting the expulsion of the air without developing excessive back pressure, a noncollapsible metal float which will close the valve and prevent the loss of water from the system, an air seal that will effectively close and prevent the re-entry of air into the system when subatmospheric pressures prevail therein, and a thermostatic member that will close the port against the passage of steam from the system. The name of the manufacturer shall be clearly stamped on the outside of each valve. The air vent valve shall be suitable for the pressure rating of the piping system.

#### 2.10.18 Test Plugs

Provide a test plug with 1/4 inch fittings where indicated on the drawings, to receive either a temperature or pressure probe 1/8 inch O.D. Fitting shall be solid brass with two valve cores of Neoprene rated at 500 psig at 200 degrees F and shall be fitted with a color coded cap strap with gasket rated at 1000 psi at 140 degrees F. In addition, contractor shall supply and present to the Government on completion of system testing a pressure and temperature test kit. Test Kits shall include 0-100 psig pressure gauge with a number 500 gauge adapter attached, 25-125 degrees F and a 0-220 degree F pocket testing thermometers, extra number 500 gauge adapter and protective carrying case with foam inserts.

#### 2.11 ELECTRICAL EQUIPMENT

Electric motor-driven equipment shall be provided complete with motors, motor starters, and necessary control devices. Electrical equipment, motor control devices, motor efficiencies and wiring shall be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Motors which are not an integral part of a packaged boiler and which are integral in size shall be the premium efficiency type in accordance with NEMA MG 1. Motors which are an integral part of the packaged boiler shall be the highest efficiency available by the manufacturer of the packaged boiler. Motor starters shall be provided complete with properly sized thermal overload protections and other appurtenances necessary for the motor control

specified. Starters shall be furnished in general purpose enclosures. Manual or automatic control and protective or signal devices required for the operation specified and any control wiring required for controls and devices but not shown shall be provided.

#### 2.11.1 Motor Ratings

Motors shall be suitable for the voltage and frequency provided. Motors 1/2 hp and larger shall be three-phase, unless otherwise indicated. Motors shall be of sufficient capacity to drive the equipment at the specified capacity without exceeding the nameplate rating on the motor.

#### 2.11.2 Motor Controls

Motor controllers shall be provided complete with properly sized thermal overload protection. Manual or automatic control and protective or signal devices required for the operation specified and any wiring required to such devices shall be provided. Where two-speed or variable-speed motors are indicated, solid-state variable-speed controllers may be provided to accomplish the same function. Solid state variable speed controllers shall be utilized for fractional through 10 hp ratings. Adjustable frequency drives shall be used for larger motors.

#### 2.12 INSULATION

Shop and field-applied insulation shall be as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

#### 2.13 TOOLS

Special tools shall be furnished. Special tools shall include uncommon tools necessary for the operation and maintenance of boilers, burners, pumps, fans, controls, meters, special piping systems, and other equipment. Small hand tools shall be furnished within a suitable cabinet, mounted where directed.

##### 2.13.1 Wrenches

Wrenches shall be provided as required for specialty fittings such as manholes, handholes, and cleanouts. One set of extra gaskets shall be provided for all manholes and handholes, for pump barrels, and other similar items of equipment. Gaskets shall be packaged and properly identified.

#### 2.14 BOILER WATER TREATMENT

Submit six complete copies of the proposed water treatment plan. The plan shall include a layout, control scheme, a list of the existing water conditions including the items listed in this paragraph, a list of all chemicals, the proportion of chemicals to be added, the final treated water conditions, and a description of environmental concerns for handling the chemicals. The water treatment system shall be capable of feeding chemicals and bleeding the system to prevent corrosion and scale within the boiler and piping distribution system. Submit 6 complete copies of operating and maintenance manuals for the step-by-step water treatment procedures, including procedures for testing the water quality. The water shall be treated to maintain the conditions recommended by the boiler manufacturer. Chemicals shall meet required federal, state, and local environmental regulations for the treatment of boilers and discharge to

the sanitary sewer. The services of a company regularly engaged in the treatment of boilers shall be used to determine the correct chemicals and concentrations required for water treatment. The company shall maintain the chemical treatment and provide all chemicals required for a period of 1 year from the date of occupancy. Filming amines and proprietary chemicals shall not be used. The water treatment chemicals shall remain stable throughout the operating temperature range of the system and shall be compatible with pump seals and other elements of the system.

#### 2.14.1 MakeUp Water Analysis

Water treatment provider shall provide a water quality analysis for water available at Project site.

#### 2.14.2 Boiler Water Limits

The boiler manufacturer shall be consulted for the determination of the boiler water chemical composition limits. The boiler water limits shall be as follows unless dictated differently by the boiler manufacturer's recommendations:

Sodium Sulfite	20-40 ppm
Hardness	Less than 2 ppm
pH	9.3 - 9.9

#### 2.14.3 Chemical Shot Feeder

A shot feeder shall be provided as indicated. Size and capacity of feeder shall be based upon local requirements and water analysis. The feeder shall be furnished with an air vent, gauge glass, funnel, valves, fittings, and piping.

#### 2.14.4 Chemical Piping

The piping and fittings shall be constructed of schedule 80 PVC for connection to systems with a maximum operating temperature of 100 degrees F and Schedule 80 CPVC for connection to systems with a maximum operating temperature of 190 degree F. All chemical piping, valves and fittings shall be fully compatible with the treatment chemicals in use.

#### 2.14.5 Test Kits

One test kit of each type required to determine the water quality as outlined within the operation and maintenance manuals shall be provided.

#### 2.15 BUFFER TANKS

Hot water buffer tanks shall be designed and constructed per ASME Code, Section VIII, Division 1 and registered with the national Board of Pressure Vessel Manufacturers. Hot water buffer tanks shall be provided with flanged pipe connections sized and located as indicated on the drawings. Tanks shall be vertical with solid internal baffle and base ring. Provide raised nameplate. Hot water buffer tanks shall be insulated in accordance with the requirements of Section 23 07 00, THERMAL INSULATION FOR MECHANICAL SYSTEMS.

### PART 3 EXECUTION

#### 3.1 EXAMINATION

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

#### 3.2 ERECTION OF BOILER AND AUXILIARY EQUIPMENT

Boiler and auxiliary equipment shall be installed in accordance with manufacturer's written instructions. Proper provision shall be made for expansion and contraction between boiler foundation and floor. This joint shall be packed with suitable nonasbestos rope and filled with suitable compound that will not become soft at a temperature of 100 degrees F. Boilers and firing equipment shall be supported from the foundations by structural steel completely independent of all brickwork. Boiler supports shall permit free expansion and contraction of each portion of the boiler without placing undue stress on any part of the boiler or setting. Boiler breeching shall be as indicated with full provision for expansion and contraction between all interconnected components.

#### 3.3 PIPING INSTALLATION

Unless otherwise specified, nonboiler external pipe and fittings shall conform to the requirements of ASME B31.1. Pipe installed shall be cut accurately to suit field conditions, shall be installed without springing or forcing, and shall properly clear windows, doors, and other openings. Cutting or other weakening of the building structure to facilitate piping installation will not be permitted. Pipes shall be free of burrs, oil, grease and other foreign material and shall be installed to permit free expansion and contraction without damaging the building structure, pipe, pipe joints, or pipe supports. Changes in direction shall be made with fittings, except that bending of pipe 1 inch and smaller will be permitted provided a pipe bender is used and wide sweep bends are formed. The centerline radius of bends shall not be less than 6 diameters of the pipe. Bent pipe showing kinks, wrinkles, flattening, or other malformations will not be accepted. Vent pipes shall be carried through the roof as directed and shall be properly flashed. Unless otherwise indicated, horizontal supply mains shall pitch down in the direction of flow with a grade of not less than 1 inch in 40 feet. Open ends of pipelines and equipment shall be properly capped or plugged during installation to keep dirt or other foreign materials out of the systems. Pipe not otherwise specified shall be uncoated. Unless otherwise specified or shown, final connections to equipment shall be made with malleable-iron unions for steel pipe 2-1/2 inches or less in diameter and with flanges for pipe 3 inches or more in diameter. Unions for copper pipe or tubing shall be brass or bronze. Reducing fittings shall be used for changes in pipe sizes. In horizontal hot water lines, reducing fittings shall be eccentric type to maintain the top of the lines at the same level to prevent air binding.

##### 3.3.1 Heating Water Piping and Fittings

Pipe shall be black steel or copper tubing. Fittings for steel piping shall be black malleable iron or cast iron to suit piping. Fittings adjacent to valves shall suit valve material.

### 3.3.2 Pipe Flushing

a. A proper flushing plan is the responsibility of the Contractor and includes the following:

1. Adequate flushing taps to promote sufficient flow velocity detailed herein.
2. Means of circulating flow whether a rental pump or system pump. Consult the Contracting Officer or Architect/Engineer if a system pump is to be used. Obtain a letter from the pump manufacturer confirming no warranties will be voided.
3. Start-up strainers should be inserted into pumps with a 40-micro mesh if not provided by pump manufacturer.

b. The flushing plan, including tap location drawing, shall be submitted to the Contracting Officer and/or Architect/Engineer for approval prior to commencement.

c. Flush the system with clean water. Remove, clean, and replace any strainer screens throughout the flushing process to ensure no plugging occurs.

d. Flushing should occur with enough flow to achieve 10 feet per second (or maximum possible) to lift and flush debris. System should be flushed until clear water is observed for a minimum of 2 hours.

e. Do not flush through major equipment (i.e. chillers, boilers, heat exchangers, cooling towers, etc.) Install means to jumper around this equipment.

f. Post flushing, for cleaning passivation, circulate cleaning chemicals at a reduced velocity between 3 and 6 feet per second. Flush until alkalinity is below 30 ppm and iron less than 2 ppm as determined by a water analysis. Consult water treatment Contractor for chemical injection.

g. Drain at all system low points (drip legs, etc.) when flushing is complete.

h. Remove start-up strainers and insert normal operating strainers.

i. If system will be dry for any period of time, charge the piping with nitrogen to 5 PSIG to prevent rusting.

### 3.3.3 Vent Piping and Fittings

Vent piping shall be black steel. Fittings shall be black malleable iron or cast iron to suit piping.

### 3.3.4 Gauge Piping

Piping shall be copper tubing.

### 3.3.5 Joints

Joints between sections of steel pipe and between steel pipe and fittings shall be threaded, flanged or welded as indicated or specified. Except as



otherwise specified, fittings 1 inch and smaller shall be threaded; fittings 1-1/4 inches and up to but not including 3 inches shall be either threaded, grooved, or welded; and fittings 3 inches and larger shall be either flanged, grooved, or welded. Pipe and fittings 1-1/4 inches and larger installed in inaccessible conduit or trenches beneath concrete floor slabs shall be welded. Connections to equipment shall be made with black malleable-iron unions for pipe 2-1/2 inches or smaller in diameter and with flanges for pipe 3 inches or larger in diameter. Joints between sections of copper tubing or pipe shall be flared, soldered, or brazed.

#### 3.3.5.1 Threaded Joints

Threaded joints shall be made with tapered threads properly cut and shall be made perfectly tight with a stiff mixture of graphite and oil or with polytetrafluoroethylene tape applied to the male threads only and in no case to the fittings.

#### 3.3.5.2 Welded Joints

Welded joints shall be in accordance with paragraph GENERAL REQUIREMENTS unless otherwise specified. Changes in direction of piping shall 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 connections may be made with either welding tees or forged branch outlet fittings, either being acceptable without size limitation. Branch outlet fittings, where used, shall be forged, flared for improved flow characteristics where attached to the run, reinforced against external strains, and designed to withstand full pipe bursting strength. Socket weld joints shall be assembled so that the space between the end of the pipe and the bottom of the socket is no less than 1/16 inch and no more than 1/8 inch.

#### 3.3.5.3 Flared and Brazed Copper Pipe and Tubing

Tubing shall be cut square, and burrs shall be removed. Both inside of fittings and outside of tubing shall be cleaned thoroughly with sand cloth or steel wire brush before brazing. Annealing of fittings and hard-drawn tubing shall not occur when making connections. Installation shall 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. Brazed joints shall be made in conformance with AWS B2.2/B2.2M and CDA A4015 with flux. Copper-to-copper joints shall include the use of copper-phosphorous or copper-phosphorous-silver brazing metal without flux. Brazing of dissimilar metals (copper to bronze or brass) shall include the use of flux with either a copper-phosphorous, copper-phosphorous-silver or a silver brazing filler metal. Joints for flared fittings shall be of the compression pattern. Swing joints or offsets shall be provided in all branch connections, mains, and risers to provide for expansion and contraction forces without undue stress to the fittings or to short lengths of pipe or tubing. Flared or brazed copper tubing to pipe adapters shall be provided where necessary for joining threaded pipe to copper tubing.

#### 3.3.5.4 Soldered Joints

Soldered joints shall be made with flux and are only acceptable for lines 2 inches and smaller. Soldered joints shall conform to ASME B31.5 and CDA A4015.

### 3.3.5.5 Copper Tube Extracted Joint

An extruded mechanical tee joint may be made in copper tube. Joint shall be produced with an appropriate tool by drilling a pilot hole and drawing out the tube surface to form a collar having a minimum height of three times the thickness of the tube wall. To prevent the branch tube from being inserted beyond the depth of the extracted joint, dimpled depth stops shall be provided. The branch tube shall be notched for proper penetration into fitting to assure a free flow joint. Extracted joints shall be brazed using a copper phosphorous classification brazing filler metal. Soldered joints will not be permitted.

### 3.3.6 Flanges and Unions

Flanges shall be faced true, provided with 1/16 inch thick gaskets, and made square and tight. Where steel flanges mate with cast-iron flanged fittings, valves, or equipment, they shall be provided with flat faces and full face gaskets. Union or flange joints shall be provided in each line immediately preceding the connection to each piece of equipment or material requiring maintenance such as coils, pumps, control valves, and other similar items. Dielectric pipe unions shall be provided between ferrous and nonferrous piping 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 1 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.

### 3.3.7 Branch Connections

#### 3.3.7.1 Branch Connections for Hot Water Systems

Branches from the main shall pitch up or down as shown to prevent air entrapment. Connections shall ensure unrestricted circulation, eliminate air pockets, and permit complete drainage of the system. Branches shall pitch with a grade of not less than 1 inch in 10 feet. When indicated, special flow fittings shall be installed on the mains to bypass portions of the water through each radiator. Special flow fittings shall be standard catalog products and shall be installed as recommended by the manufacturer.

### 3.3.8 Flared, Brazed, and Soldered Copper Pipe and Tubing

Copper tubing shall be flared, brazed, or soldered. Tubing shall be cut square, and burrs shall be removed. Both inside of fittings and outside of tubing shall be cleaned thoroughly with sand cloth or steel wire brush before brazing. Annealing of fittings and hard-drawn tubing shall not occur when making connections. Installation shall 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 for flared fittings shall be of the compression pattern. Swing joints or offsets shall be provided on branch connections, mains, and risers to provide for expansion and contraction forces without undue stress to the fittings or to short lengths of pipe or tubing. Pipe adapters shall be provided where necessary for joining threaded pipe to copper tubing. Brazed joints shall be made in conformance with CDA A4015. Copper-to-copper joints shall include the use of copper-phosphorous or copper-phosphorous-silver brazing metal without flux. Brazing of

dissimilar metals (copper to bronze or brass) shall include the use of flux with either a copper-phosphorous, copper-phosphorous-silver, or a silver brazing filler metal. Soldered joints shall be made with flux and are only acceptable for lines 2 inches or smaller. Soldered joints shall conform to ASME B31.5 and shall be in accordance with CDA A4015.

### 3.3.9 Copper Tube Extracted Joint

An extracted mechanical tee joint may be made in copper tube. Joint shall be produced with an appropriate tool by drilling a pilot hole and drawing out the tube surface to form a collar having a minimum height of three times the thickness of the tube wall. To prevent the branch tube from being inserted beyond the depth of the extracted joint, dimpled depth stops shall be provided. The branch tube shall be notched for proper penetration into fitting to assure a free flow joint. Extracted joints shall be brazed using a copper phosphorous classification brazing filler metal. Soldered joints will not be permitted.

### 3.3.10 Supports

Hangers used to support piping 2 inches and larger shall be fabricated to permit adequate adjustment after erection while still supporting the load. Pipe guides and anchors shall 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 shall be supported by variable spring hangers and supports or by constant support hangers. Threaded rods which are used for support shall not be formed or bent. Supports shall not be attached to the underside of concrete filled floors or concrete roof decks unless approved by the Contracting Officer.

#### 3.3.10.1 Vibration and Seismic Requirements for Equipment, Piping, Supports and Structural Bracing

Equipment and piping shall be provided with vibration isolators and piping, equipment and attached valves shall be supported and braced to resist seismic loads as specified in Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT, Section 23 05 48.19 SEISMIC BRACING FOR HVAC and as indicated on the drawings. Structural steel required for reinforcement to properly support piping, headers, and equipment, but not shown, shall be provided in this section. Material used for supports shall be as specified in Section 05 12 00 STRUCTURAL STEEL.

#### 3.3.10.2 Pipe Hangers, Inserts, and Supports

Pipe hangers, inserts, and supports shall conform to MSS SP-58, except as modified herein.

##### 3.3.10.2.1 Types 5, 12, and 26

Use of Types 5, 12, and 26 is prohibited.

##### 3.3.10.2.2 Type 3

Type 3 shall not be used on insulated pipe which has a vapor barrier. Type 3 may be used on insulated pipe that does not have a vapor barrier if clamped directly to the pipe, if the clamp bottom does not extend through the insulation, and if the top clamp attachment does not contact the

insulation during pipe movement.

#### 3.3.10.2.3 Type 18

Type 18 inserts shall 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.

#### 3.3.10.2.4 Type 19 and 23 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.

#### 3.3.10.2.5 Type 20 Attachments

Type 20 attachments used on angles and channels shall be furnished with an added malleable-iron heel plate or adapter.

#### 3.3.10.2.6 Type 24

Type 24 may be used only on trapeze hanger systems or on fabricated frames.

#### 3.3.10.2.7 Horizontal Pipe Supports

Horizontal pipe supports shall be spaced as specified in MSS SP-58 and a support shall be installed not over 1 foot from the pipe fitting joint at each change in direction of the piping. Pipe supports shall be spaced not over 5 feet apart at valves.

#### 3.3.10.2.8 Vertical Pipe Support

Vertical pipe shall be supported 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.

#### 3.3.10.2.9 Type 35 Guides

Type 35 guides using steel, reinforced polytetrafluoroethylene (PTFE) or graphite slides shall be provided where required to allow longitudinal pipe movement. Lateral restraints shall be provided as required. Slide materials shall be suitable for the system operating temperatures, atmospheric conditions, and bearing loads encountered.

- a. 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, a Type 39 saddle may be welded to the pipe and freely rested on a steel plate. On piping under 4 inches, a Type 40 protection shield may be attached to the pipe or insulation and freely rested on a steel slide plate.
- b. Where there are high system temperatures and welding to piping is not desirable, the Type 35 guide shall include a pipe cradle welded to the guide structure and strapped securely to the pipe. The pipe shall be separated from the slide material by at least 4 inches or by an amount adequate for the insulation, whichever is greater.

#### 3.3.10.2.10 Horizontal Insulated Pipe

Except for Type 3, pipe hangers on horizontal insulated pipe shall be the size of the outside diameter of the insulation.

#### 3.3.10.2.11 Piping in Trenches

Support piping in trenches as indicated.

#### 3.3.10.2.12 Structural Steel Attachments

Structural steel attachments and brackets required to support piping, headers, and equipment, but not shown, shall be provided under this section. Material and installation shall be as specified under Section 05 12 00 STRUCTURAL STEEL. Pipe hanger loads suspended from steel joist between panel points shall not exceed 50 pounds. Loads exceeding 50 pounds shall be suspended from panel points.

#### 3.3.10.3 Multiple Pipe Runs

In the support of multiple pipe runs on a common base member, a clip or clamp shall be used where each pipe crosses the base support member. Spacing of the base support member shall not exceed the hanger and support spacing required for any individual pipe in the multiple pipe run. The clips or clamps shall be rigidly attached to the common base member. A clearance of 1/8 inch shall be provided between the pipe insulation and the clip or clamp for piping which may be subjected to thermal expansion.

#### 3.3.11 Anchors

Anchors shall be provided where necessary to localize expansion or to prevent undue strain on piping. Anchors shall consist of heavy steel collars with lugs and bolts for clamping and attaching anchor braces, unless otherwise indicated. Anchor braces shall be installed in the most effective manner to secure the desired results, using turnbuckles where required. Supports, anchors, or stays shall not be attached where they will injure the structure or adjacent construction during installation or by the weight of expansion of the pipeline.

#### 3.3.12 Valves

Valves shall be installed where indicated, specified, and required for functioning and servicing of the systems. Valves shall be safely accessible. Swing check valves shall be installed upright in horizontal lines and in vertical lines only when flow is in the upward direction. Gate and globe valves shall be installed with stems horizontal or above. Valves to be brazed shall be disassembled prior to brazing and all packing removed. After brazing, the valves shall be allowed to cool before reassembling.

#### 3.3.12.1 Chainwheels

Install chainwheels on operators for butterfly valves NPS 6 and larger and more than 96 inches above the floor. Extend chains to 72 inches above finished floor.

#### 3.3.13 Pipe Sleeves

Pipe passing through concrete or masonry walls or concrete floors or roofs

shall be provided with pipe sleeves fitted into place at the time of construction. A waterproofing clamping flange shall be installed as indicated where membranes are involved. Sleeves shall not be installed in structural members except where indicated or approved. Rectangular and square openings shall be as detailed. Each sleeve shall extend through its respective wall, floor, or roof. Sleeves through walls shall be cut flush with wall surface. Sleeves through floors shall extend above top surface of floor a sufficient distance to allow proper flashing or finishing. Sleeves through roofs shall extend above the top surface of roof at least 6 inches for proper flashing or finishing. Unless otherwise indicated, sleeves shall be sized to provide a minimum clearance of 1/4 inch between bare pipe and sleeves or between jacket over insulation and sleeves. Sleeves in waterproofing membrane floors, bearing walls, and wet areas shall be galvanized steel pipe or cast-iron pipe. Sleeves in nonbearing walls, floors, or ceilings may be galvanized steel pipe, cast-iron pipe, or galvanized sheet metal with lock-type longitudinal seam. Except in pipe chases or interior walls, the annular space between pipe and sleeve or between jacket over insulation and sleeve in nonfire rated walls shall be sealed as indicated and specified in Section 07 92 00 JOINT SEALANTS. Metal jackets shall be provided over insulation passing through exterior walls, firewalls, fire partitions, floors, or roofs.

- a. Metal jackets shall not be thinner than 0.006 inch thick aluminum, if corrugated, and 0.016 inch thick aluminum, if smooth.
- b. Secure metal jackets with aluminum or stainless steel bands not less than 3/8 inch wide and not more than 8 inches apart. When penetrating roofs and before fitting the metal jacket into place, a 1/2 inch wide strip of sealant shall be run vertically along the inside of the longitudinal joint of the metal jacket from a point below the backup material to a minimum height of 36 inches above the roof. If the pipe turns from vertical to horizontal, the sealant strip shall be run to a point just beyond the first elbow. When penetrating waterproofing membrane for floors, the metal jacket shall extend from a point below the back-up material to a minimum distance of 2 inches above the flashing. For other areas, the metal jacket shall extend from a point below the backup material to a point 12 inches above material to a minimum distance of 2 inches above the flashing. For other areas, the metal jacket shall extend from a point below the backup material to a point 12 inches above the floor; when passing through walls above grade, the jacket shall extend at least 4 inches beyond each side of the wall.

#### 3.3.13.1 Pipes Passing Through Waterproofing Membranes

In addition to the pipe sleeves referred to above, pipes passing through waterproofing membranes shall be provided with a 4 pound lead flashing or a 16 ounce copper flashing, each within an integral skirt or flange. Flashing shall be suitably formed, and the skirt or flange shall extend not less than 8 inches from the pipe and shall set over the membrane in a troweled coating of bituminous cement. The flashing shall extend above the roof or floor a minimum of 10 inches. The annular space between the flashing and the bare pipe or between the flashing and the metal-jacket-covered insulation shall be sealed as indicated. Pipes up to and including 10 inches in diameter which pass through waterproofing membrane may be installed through a cast-iron sleeve with caulking recess, anchor lugs, flashing clamp device, and pressure ring with brass bolts. Waterproofing membrane shall be clamped into place and sealant shall be placed in the caulking recess.

### 3.3.13.2 Optional Modular Mechanical Sealing Assembly

At the option of the Contractor, a modular mechanical type sealing assembly may be installed in the annular space between the sleeve and conduit or pipe in lieu of a waterproofing clamping flange and caulking and sealing specified above. The seals shall include 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. The links shall 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 shall cause the rubber sealing elements to expand and provide a watertight seal between the pipe/conduit and the sleeve. Each seal assembly shall be sized as recommended by the manufacturer to fit the pipe/conduit and sleeve involved.

### 3.3.13.3 Optional Counterflashing

As alternates to caulking and sealing the annular space between the pipe and flashing or metal-jacket-covered insulation and flashing, counterflashing may consist of standard roof coupling for threaded pipe up to 6 inches in diameter, lead flashing sleeve for dry vents with the sleeve turned down into the pipe to form a waterproof joint, or a tack-welded or banded-metal rain shield around the pipe, sealed as indicated.

### 3.3.13.4 Fire Seal

Where pipes pass through firewalls, fire partitions, or floors, a fire seal shall be provided as specified in Section 07 84 00 FIRESTOPPING. Firestopping materials be furnished and installed by the Firestopping installer and shall conform to the requirements in Section 07 84 00 FIRESTOPPING.

### 3.3.14 Balancing Valves

Balancing valves shall be installed as indicated.

### 3.3.15 Thermometer Wells

Provide a thermometer well in each return line for each circuit in multicircuit systems.

### 3.3.16 Air Vents

Install air vents in piping at all system high points. The vent shall remain open until water rises in the tank or pipe to a predetermined level at which time it shall close tight. An overflow pipe from the vent shall be run to a point designated by the Contracting Officer's representative. The inlet to the air vent shall have a gate valve or ball valve.

### 3.3.17 Escutcheons

Provide escutcheons at all finished surfaces where exposed piping, bare or insulated, passes through floors, walls, or ceilings except in boiler, utility, or equipment rooms. Escutcheons shall be fastened securely to pipe or pipe covering and shall be chromium-plated iron or chromium-plated

brass, either one-piece or split pattern, held in place by internal spring tension or setscrews.

### 3.3.18 Drains

A drain connection with a 1 inch gate valve or 3/4 inch hose bib shall be installed at the lowest point in the return main near the boiler. In addition, threaded drain connections with threaded cap or plug shall be installed on the heat exchanger coil on each unit heater or unit ventilator and wherever required for thorough draining of the system.

### 3.3.19 Strainer Blow-Down Piping

Strainer blow-down connections shall be fitted with a black steel blow-down pipeline routed to an accessible location and provided with a blow-down valve.

### 3.3.20 Direct Venting for Combustion Intake Air and Exhaust Air

The intake air and exhaust vents shall be installed in accordance with NFPA 54 and boiler manufacturer's recommendations. The exhaust vent shall be sloped 1/4 inch/ft toward the boiler's flue gas condensate collection point.

## 3.4 GAS FUEL SYSTEM

Gas piping, fittings, valves, regulators, tests, cleaning, and adjustments shall be in accordance with the Section 23 11 25 FACILITY GAS PIPING. Submit proposed test schedules for the heating system and fuel system tests, at least 2 weeks prior to the start of related testing. NFPA 54 shall be complied with unless otherwise specified. Burners, pilots, and all accessories shall be listed in UL FLAMMABLE & COMBUSTIBLE. The fuel system shall be provided with a gas tight, manually operated, UL listed stop valve at the gas-supply connections, a gas strainer, a pressure regulator, pressure gauges, a burner-control valve, a safety shutoff valve suitable for size of burner and sequence of operation, and other components required for safe, efficient, and reliable operation as specified. Approved permanent and ready facilities to permit periodic valve leakage tests on the safety shutoff valve or valves shall be provided.

## 3.5 COLOR CODE MARKING AND FIELD PAINTING

Color code marking of piping shall be as specified in Section 09 90 00 PAINTS AND COATINGS. Ferrous metal not specified to be coated at the factory shall be cleaned, prepared, and painted as specified in Section 09 90 00 PAINTS AND COATINGS. Exposed pipe covering shall be painted as specified in Section 09 90 00 PAINTS AND COATINGS. Aluminum sheath over insulation shall not be painted.

## 3.6 MANUFACTURER'S FIELD SERVICES

Provide the services of a manufacturer's representative who is experienced in the installation, adjustment, and operation of the equipment specified to supervise the installing, adjusting, and testing of the equipment. Field services shall not be less than seven 8 hour normal working days at the job site. These field services do not include boiler fuel system commissioning services that are specified in Section 33 08 55 COMMISSIONING OF FUEL FACILITY SYSTEMS.



### 3.7 TEST OF BACKFLOW PREVENTION ASSEMBLIES

Backflow prevention assemblies shall be tested in accordance with Section 22 00 00 PLUMBING, GENERAL PURPOSE.

### 3.8 HEATING SYSTEM TESTS

Submit the Qualifications of the firms in charge of installation and testing as specified. Submit a statement from the firms proposed to prepare submittals and perform installation and testing, demonstrating successful completion of similar services of at least five projects of similar size or scope, at least 2 weeks prior to the submittal of any other item required by this section. Before any covering is installed on pipe or heating equipment, the entire heating system's piping, fittings, and terminal heating units shall be hydrostatically tested and proved tight at a pressure of 1.5 times the design working pressure, but not less than 100 psi. Submit proposed test procedures for the heating system tests and fuel system tests, at least 2 weeks prior to the start of related testing.

- a. Before pressurizing system for test, items or equipment (e.g., vessels, pumps, instruments, controls, relief valves) rated for pressures below the test pressure shall be blanked off or replaced with spool pieces.
- b. Before balancing and final operating test, test blanks and spool pieces shall be removed; and protected instruments and equipment shall be reconnected. With equipment items protected, the system shall be pressurized to test pressure. Pressure shall be held for a period of time sufficient to inspect all welds, joints, and connections for leaks, but not less than 2 hours. Snow melt system shall be hydrostatically tested for 4 hours in accordance with HI-004. No loss of pressure will be allowed. Leaks shall be repaired and repaired joints shall be retested.
- c. Repair joints shall not be allowed under the floor for snow melt heating systems. If a leak occurs in tubing located under the floor in radiant heating systems, the entire zone that is leaking shall be replaced. If any repair is made above the floor for floor radiant heating systems, access shall be provided for the installed joint. Caulking of joints shall not be permitted.
- d. System shall be drained and after instruments and equipment are reconnected, the system shall be refilled with service medium and maximum operating pressure applied. The pressure shall be held while inspecting these joints and connections for leaks. The leaks shall be repaired and the repaired joints retested.

Upon completion of hydrostatic tests and before acceptance of the installation, submit test reports for the heating system tests. Upon completion of testing complete with results, balance the heating system in accordance with Section 23 05 93 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS and operating tests required to demonstrate satisfactory functional and operational efficiency. The operating test shall cover a period of at least 24 hours for each system, and shall include, as a minimum, the following specific information in a report, together with conclusions as to the adequacy of the system:

- a. Certification of balancing.
- b. Time, date, and duration of test.
- c. Outside and inside dry bulb temperatures.
- d. Temperature of hot water supply leaving boiler.
- e. Temperature of heating return water from system at boiler inlet.
- f. Quantity of water feed to boiler.
- g. Boiler make, type, serial number, design pressure, and rated capacity.
- h. Fuel burner make, model, and rated capacity; ammeter and voltmeter readings for burner motor.
- i. Circulating and distribution pump make, model, and rated capacity, and ammeter and voltmeter readings for pump motor during operation.
- j. Flue-gas temperature at boiler outlet.
- k. Percent carbon dioxide in flue-gas.
- l. Grade or type and calorific value of fuel.
- m. Draft at boiler flue-gas exit.
- n. Draft or pressure in furnace.
- o. Quantity of water circulated.
- p. Quantity of fuel consumed.
- q. Stack emission pollutants concentration.

Indicating instruments shall be read at half-hour intervals unless otherwise directed. Furnish all instruments, equipment, and personnel required for the tests and balancing. Obtain necessary natural gas, water and electricity. Provide necessary quantities of No. 2 fuel oil when propane gas or fuel oil is require for testing. Operating tests shall demonstrate that fuel burners and combustion and safety controls meet the requirements of ASME CSD-1 and ANSI Z21.13/CSA 4.9

#### 3.8.1 Boiler/Piping Test

At the conclusion of the 1 year period, the boiler and condensate piping shall be inspected for problems due to corrosion and scale. If the boiler is found not to conform to the manufacturer's recommendations, and the water treatment company recommendations have been followed, the water treatment company shall provide all chemicals and labor for cleaning or repairing the equipment as required by the manufacturer's recommendations. If corrosion is found within the condensate piping, proper repairs shall be made by the water treatment company.

### 3.9 CLEANING

#### 3.9.1 Boilers and Piping

After the hydrostatic tests have been made and before the system is balanced and operating tests are performed, the boilers and piping shall be thoroughly cleaned by filling the system with a solution consisting of either 1 pound of caustic soda or 1 pound of trisodium phosphate per 50 gallons of water. The proper safety precautions shall be observed in the handling and use of these chemicals. The water shall be heated to approximately 150 degrees F and the solution circulated in the system for a period of 48 hours. The system shall then be drained and thoroughly flushed out with fresh water. Strainers and valves shall be thoroughly cleaned. Prior to operating tests, air shall be removed from all water systems by operating the air vents.

#### 3.9.2 Heating Units

Inside space heating equipment, ducts, plenums, and casing shall be thoroughly cleaned of debris and blown free of small particles of rubbish and dust and then vacuum cleaned before installing outlet faces. Equipment shall be wiped clean, with all traces of oil, dust, dirt, or paint spots removed. Temporary filters shall be provided for fans that are operated during construction, and new filters shall be installed after construction dirt has been removed from the building, and the ducts, plenum, casings, and other items specified have been vacuum cleaned. System shall be maintained in this clean condition until final acceptance. Bearings shall be properly lubricated with oil or grease as recommended by the manufacturer. Belts shall be tightened to proper tension. Control valves and other miscellaneous equipment requiring adjustment shall be adjusted to setting indicated or directed. Fans shall be adjusted to the speed indicated by the manufacturer to meet specified conditions.

#### 3.10 FIELD TRAINING

Conduct a training course for the operating staff as designated by the Contracting Officer. The training period shall consist of a total of 8 hours of normal working time and shall start after the system is functionally completed but prior to final acceptance tests.

- a. The field instructions shall cover all of the items contained in the approved operation and maintenance manuals, as well as demonstrations of routine maintenance operations and boiler safety devices.
- b. Submit operations and maintenance facility data in accordance with Section 01 78 24.00 10 OPERATING AND MAINTENANCE FACILITY DATA REQUIREMENTS
- c. Notify the Contracting Officer at least 14 days prior to date of proposed conduction of the training course.

#### 3.11 FUEL SYSTEM TESTS

Submit test reports for the fuel system tests, upon completion of testing complete with results.

3.11.1 Gas System Test

The gas fuel system shall be tested in accordance with the test procedures outlined in NFPA 54.

-- End of Section --



SECTION 23 64 10

WATER CHILLERS, VAPOR COMPRESSION TYPE  
11/16

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 550/590 I-P (2015; ERTA 2016) Performance Rating Of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle

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

ANSI/ASHRAE 15 & 34 (2022) ANSI/ASHRAE Standard 15-Safety Standard for Refrigeration Systems and ANSI/ASHRAE Standard 34-Designation and Safety Classification of Refrigerants

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

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

AMERICAN WELDING SOCIETY (AWS)

AWS Z49.1 (2012) Safety in Welding and Cutting and Allied Processes

ASTM INTERNATIONAL (ASTM)

ASTM A307 (2021) Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength

ASTM B117 (2019) Standard Practice for Operating Salt Spray (Fog) Apparatus

ASTM D520 (2000; R 2011) Zinc Dust Pigment

ASTM E84 (2023) Standard Test Method for Surface Burning Characteristics of Building Materials

ASTM F104 (2011; R 2020) Standard Classification System for Nonmetallic Gasket Materials

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA MG 1 (2021) Motors and Generators

NEMA MG 11 (1977; R 2012) Energy Management Guide for  
Selection and Use of Single Phase Motors

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

40 CFR 82 Protection of Stratospheric Ozone

## 1.2 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. 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

Water Chiller; G

Verification of Dimensions; G

System Performance Tests; G

Demonstrations; G

Refrigerant; G

Water Chiller - Field Acceptance Test Plan; G

### SD-06 Test Reports

Field Acceptance Testing; G

Water Chiller - Field Acceptance Test Report; G

System Performance Tests; G

### SD-07 Certificates

Refrigeration System; G

Ozone Depleting Substances Technician Certification; G

### SD-08 Manufacturer's Instructions

Water Chiller - Installation Instructions; G

### SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G

### SD-11 Closeout Submittals

Indoor Air Quality During Construction; S

### 1.3 CERTIFICATIONS

#### 1.3.1 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 SAFETY REQUIREMENTS

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.

### 1.5 DELIVERY, STORAGE, AND HANDLING

Stored items must be protected 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 will be the Contractor's responsibility. Any materials found to be damaged must be replaced at the Contractor's expense. During installation, piping and similar openings must be capped to keep out dirt and other foreign matter.

### 1.6 PROJECT REQUIREMENTS

#### 1.6.1 Verification of Dimensions

The Contractor must become 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.

## PART 2 PRODUCTS

### 2.1 PRODUCTS

#### 2.1.1 SOLE SOURCE MANUFACTURER

Chillers shall be sole sourced TRANE.

#### 2.1.2 STANDARD REQUIREMENTS

Materials and equipment will be standard Commercial cataloged products of a manufacturer regularly engaged in the manufacturing of such products, which are of a similar material, design and workmanship. These products must have a two year record of satisfactory field service prior to bid opening. The two year record of service must include applications of equipment and materials under similar circumstances and of similar size. Products having less than a two year record of satisfactory field service will be acceptable if a certified record of satisfactory field service for not less than 6000 hours can be shown. The 6000 hour service record must not include any manufacturer's prototype or factory testing. Satisfactory field service must have been completed by a product that has been, and presently is being sold or offered for sale on the commercial market



through the following copyrighted means: advertisements, manufacturer's catalogs, or brochures.

## 2.2 MANUFACTURER'S STANDARD NAMEPLATES

Major equipment including chillers, compressors, compressor drivers, condensers, water coolers, receivers, refrigerant leak detectors, 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. Plates must be fixed in prominent locations with nonferrous screws or bolts.

Nameplates are required on major components if the manufacturer needs to provide specific engineering and manufacturing information pertaining to the particular component. Should replacement of this component be required, nameplate information will insure correct operation of the unit after replacement of this component.

## 2.3 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. 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, must be provided. For packaged equipment, the manufacturer must provide controllers including 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.
- 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.
- 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. 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. Provide motor starters complete with thermal overload protection and other necessary appurtenances. Motor enclosure type may be either TEAO or TEFC.
- e. Use adjustable frequency drives for all variable-speed motor applications. Provide variable frequency drives for motors as specified in Section 26 29 23 ADJUSTABLE SPEED DRIVE (ASD) SYSTEMS UNDER 600 VOLTS.

- f. Provide inverter duty premium efficiency motors for use with variable frequency drives.

#### 2.4 SELF-CONTAINED WATER CHILLERS, VAPOR COMPRESSION TYPE

Unless necessary for delivery purposes, units must be assembled, leak-tested, charged (refrigerant and oil), and adjusted at the factory. In lieu of delivery constraints, a chiller may be assembled, leak-tested, charged (refrigerant and oil), and adjusted at the job site by a factory representative. Unit components delivered separately must be sealed and charged with a nitrogen holding charge. Parts weighing 50 pounds or more which must be removed for inspection, cleaning, or repair, such as motors, gear boxes, cylinder heads, casing tops, condenser, and cooler heads, must have lifting eyes or lugs. Chiller must be provided with a single point wiring connection for incoming power supply. Chiller's condenser and water cooler must be provided with standard water boxes with flanged mechanical connections.

##### 2.4.1 Scroll Type

Chiller must be certified for performance per AHRI 550/590 I-P. If specified performance is outside of the Application Rating Conditions of AHRI 550/590 I-P, Table 2 then the chiller's performance must be rated in accordance with AHRI 550/590 I-P. Chiller must conform to ANSI/ASHRAE 15 & 34. As a minimum, chiller must include the following components as defined in paragraph CHILLER COMPONENTS.

- a. Refrigerant and oil
- b. Structural base
- c. Chiller refrigerant circuit
- d. Controls package
- e. Scroll compressor
- f. Compressor driver, electric motor
- g. Compressor driver connection
- h. Water cooler (evaporator)
- i. Air-cooled condenser coil

#### 2.5 CHILLER COMPONENTS

##### 2.5.1 Refrigerant and Oil

Refrigerants must be one of the fluorocarbon gases. Refrigerants must have number designations and safety classifications in accordance with ANSI/ASHRAE 15 & 34. CFC-based refrigerants are prohibited. Refrigerants must have an Ozone Depletion Potential (ODP) no greater than 0.0, with the exception of R-123. Provide SDS sheets for all refrigerants.

##### 2.5.2 Structural Base

Chiller and individual chiller components must be provided with a factory-mounted structural steel base (welded or bolted) or support

legs. Chiller and individual chiller components must be isolated from the building structure by means of molded neoprene isolation pads.

### 2.5.3 Chiller Refrigerant Circuit

Chiller refrigerant circuit must be completely piped and factory leak tested in accordance with ANSI/ASHRAE 15 & 34. For multicompressor units, not less than 2 independent refrigerant circuits must be provided. Circuit must include as a minimum a combination filter and drier, combination sight glass and moisture indicator, an electronic or thermostatic expansion valve with external equalizer or float valve, charging ports, compressor service valves for field-serviceable compressors, and superheat adjustment.

### 2.5.4 Controls Package

Provide chillers with a complete factory-mounted, microprocessor based operating and safety control system. Controls package must contain as a minimum a digital display, an on-auto-off switch, motor starters, variable frequency motor controller, disconnect switches, power wiring, and control wiring. Controls package must provide operating controls, monitoring capabilities, programmable setpoints, safety controls, and interfaces as defined below.

#### 2.5.4.1 Operating Controls

Chiller must be provided with the following adjustable operating controls as a minimum.

- a. Leaving chilled water temperature control
- b. Adjustable timer or automated controls to prevent a compressor from short cycling
- c. Automatic lead/lag controls (adjustable) for multi-compressor units
- d. Load limiting
- e. System capacity control to adjust the unit capacity in accordance with the system load and the programmable setpoints. Controls must automatically re-cycle the chiller on power interruption.
- f. Startup and head pressure controls to allow system operation at all ambient temperatures down to -10degrees F.
- g. Fan sequencing for air-cooled condenser

#### 2.5.4.2 Monitoring Capabilities

During normal operations, the control system must be capable of monitoring and displaying the following operating parameters. Access and operation of display must not require opening or removing any panels or doors.

- a. Entering and leaving chilled water temperatures
- b. Self diagnostic
- c. Operation status

- d. Operating hours
- e. Number of starts
- f. Compressor status (on or off)
- g. Compressor load (percent)
- h. Refrigerant discharge and suction pressures
- i. Oil pressure

#### 2.5.4.3 Configurable Setpoints

The control system must be capable of being configured directly at the unit's interface panel. No parameters may be capable of being changed without first entering a security access code. The programmable setpoints must include the following as a minimum:

- a. Leaving Chilled Water Temperature

#### 2.5.4.4 Safety Controls with Manual Reset

Chiller must be provided with the following safety controls which automatically shutdown the chiller and which require manual reset.

- a. Low chilled water temperature protection
- b. High condenser refrigerant discharge pressure protection
- c. Low evaporator pressure protection
- d. Chilled water flow detection
- e. High motor winding temperature protection
- f. Low oil flow protection if applicable
- g. Motor current overload and phase loss protection

#### 2.5.4.5 Safety Controls with Automatic Reset

Chiller must be provided with the following safety controls which automatically shutdown the chiller and which provide automatic reset.

- a. Over/under voltage protection
- b. Chilled water flow interlock

#### 2.5.4.6 Remote Alarm

During the initiation of a safety shutdown, a chiller's control system must be capable of activating a remote alarm bell. In coordination with the chiller, the Contractor must provide an alarm circuit (including transformer if applicable) and a minimum 4 inch diameter alarm bell. Alarm circuit must activate bell in the event of machine shutdown due to the chiller's monitoring of safety controls. The alarm bell must not sound for a chiller that uses low-pressure cutout as an operating control.

#### 2.5.4.7 Utility Monitoring and Control System Interface

Provide a Utility Monitoring and Control System (UMCS) interface meeting the requirements of Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and the requirements of Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS. The interface must provide all system operating conditions, capacity controls, and safety shutdown conditions as network points. In addition, the following points must be overridable via the network interface:

- a. Unit Start/Stop
- b. Leaving Chilled Water Temperature Setpoint

#### 2.5.5 Compressor(s)

##### 2.5.5.1 Scroll Compressor(s)

Compressors must be of the hermetically sealed design. Compressors must be mounted on vibration isolators to minimize vibration and noise. Rotating parts must be statically and dynamically balanced at the factory to minimize vibration. Lubrication system must be centrifugal pump type equipped with a means for determining oil level and an oil charging valve. Crankcase oil heater must be provided. Provide continuous compressor unloading to 10 percent of full-load capacity by way of variable speed compressor motor controller or variable unloading of the scroll.

#### 2.5.6 Compressor Driver, Electric Motor

Components such as motors, starters, variable speed drives and wiring must be in accordance with paragraph ELECTRICAL WORK. Variable frequency drive must be unit mounted as indicated.

#### 2.5.7 Compressor Driver Connections

Each compressor must be driven by a V-belt drive or direct connected through a flexible coupling, except that flexible coupling is not required on hermetic units. V-belt drives must be designed for not less than 150 percent of the driving motor capacity. Flexible couplings must be of the type that does not require lubrication.

#### 2.5.8 Water Cooler (Evaporator)

Cooler must be of the shell-and-coil or shell-and-tube type design. Cooler shell must be constructed of seamless or welded steel. Coil bundles must be totally removable and arranged to drain completely. Tubes must be seamless copper, plain, integrally finned with smooth bore or integrally finned with enhanced bore. Each tube must be individually replaceable. Tubes must be installed into carbon mild steel tube sheets by rolling. Tube baffles must be properly spaced to provide adequate tube support and cross flow. Performance must be based on a water velocity not less than 3 fps nor more than 12 fps and a fouling factor per AHRI 550/590 I-P.

Brazed plate heat exchanger must be constructed of 304 or 316 stainless steel, designed to a refrigerant-side working pressure of 430 psig and a waterside working pressure of 150 psig. Evaporator must be factory tested at 1.1 times maximum allowable refrigerant side working pressure and 1.5

times maximum allowable water side working pressure. Provide cooler heaters to protect the evaporator to an ambient of minus 20 degrees F. Provide cooler with factory-installed flow switches. All water connections must use either flanged or grooved-pipe connections. Factory insulate all cold surfaces.

#### 2.5.9 Air-Cooled Condenser Coil

The condenser coil must be of the microchannel heat exchanger technology (MCHX) type consisting of a series of flat tubes containing a series of multiple, parallel flow microchannels layered between the refrigerant manifolds in a two-pass arrangement. Provide coils constructed of aluminum alloys for fins, tubes, and manifolds. Coil must be factory leak and pressure tested after assembly in accordance with ANSI/ASHRAE 15 & 34.

Coil must be entirely coated in accordance with the requirements of paragraph COIL CORROSION PROTECTION.

#### 2.5.10 Receivers

Receiver must bear a stamp certifying compliance with ASME BPVC SEC VIII D1 and must meet the requirements of ANSI/ASHRAE 15 & 34. Inner surfaces must be thoroughly cleaned by sandblasting or other approved means. Each receiver must have a storage capacity not less than 20 percent in excess of that required for the fully-charged system. Each receiver must be equipped with inlet, outlet drop pipe, drain plug, purging valve, relief valves of capacity and setting required by ANSI/ASHRAE 15 & 34, and two bull's eye liquid-level sight glasses. Sight glasses must be in the same vertical plane, 90 degrees apart, perpendicular to the axis of the receiver, and not over 3 inches horizontally from the drop pipe measured along the axis of the receiver. In lieu of bull's eye sight glass, external gauge glass with metal glass guard and automatic closing stop valves may be provided.

#### 2.5.11 Chiller Purge System

Chillers which operate at pressures below atmospheric pressure must be provided with a purge system. Purge system must automatically remove air, water vapor, and non-condensable gases from the chiller's refrigerant while keeping refrigerant emissions below requirements of ASHRAE Std 147. Purge units must be certified per AHRI 580. Purge system must condense, separate, and return all refrigerant back to the chiller. An oil separator must be provided with the purge system if required by the manufacturer. Purge system must not discharge to occupied areas, or create a potential hazard to personnel. Purge system must include a purge pressure gauge, number of starts counter, and an elapsed time meter. Purge system must include lights or an alarm which indicate excessive purge or an abnormal air leakage into chiller.

### 2.6 ACCESSORIES

#### 2.6.1 Refrigerant Relief Valve/Rupture Disc Assembly

The assembly must be a combination pressure relief valve and rupture disc designed for refrigerant usage. The assembly must be in accordance with ASME BPVC SEC VIII D1 and ANSI/ASHRAE 15 & 34. The assembly must be provided with a pressure gauge assembly which will provide local indication if a rupture disc is broken. Rupture disc must be the non-fragmenting type.

## 2.6.2 Refrigerant Signs

Refrigerant signs must be a medium-weight aluminum type with a baked enamel finish. Signs must be suitable for indoor or outdoor service. Signs must have a white background with red letters not less than 0.5 inches in height.

### 2.6.2.1 Installation Identification

Each new refrigerating system must be provided with a refrigerant sign which indicates the following as a minimum:

- a. Contractor's name.
- b. Refrigerant number and amount of refrigerant.
- c. The lubricant identity and amount.
- d. Field test pressure applied.

### 2.6.2.2 Controls and Piping Identification

Refrigerant systems containing more than 110 lb of refrigerant must be provided with refrigerant signs which designate the following as a minimum:

- a. Valves or switches for controlling the refrigerant flow and the refrigerant compressor(s).
- b. Pressure limiting device(s).

## 2.6.3 Gaskets

Gaskets must conform to ASTM F104 - classification for compressed sheet with nitrile binder and acrylic fibers for maximum 700 degrees F service.

## 2.6.4 Bolts and Nuts

Bolts and nuts, except as required for piping applications, must be in accordance with ASTM A307. The bolt head must be marked to identify the manufacturer and the standard with which the bolt complies in accordance with ASTM A307.

## 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

Chiller must be provided with factory installed insulation on surfaces subject to sweating including the water cooler, suction line piping, economizer, and cooling lines. Insulation on heads of coolers may be field applied, however it must be installed to provide easy removal and replacement of heads without damage to the insulation. Where motors are the gas-cooled type, factory installed insulation must be provided on the cold-gas inlet connection to the motor per 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.

### 2.7.3 Coil Corrosion Protection

Provide coil with a uniformly applied phenolic 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.

## 2.8 SUPPLEMENTAL COMPONENTS/SERVICES

### 2.8.1 Chilled Water Piping and Accessories

Chilled water piping and accessories must be provided and installed in accordance with Section 23 64 26 CHILLED WATER PIPING SYSTEMS.

### 2.8.2 Temperature Controls

Chiller control packages must be fully coordinated with and integrated into the temperature control system indicated in Section 23 30 00 HVAC AIR DISTRIBUTION and Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS .

## PART 3 EXECUTION

### 3.1 INSTALLATION

Installation of water chiller systems including materials, installation, workmanship, fabrication, assembly, erection, examination, inspection, and testing must be in accordance with the manufacturer's written installation instructions, including the following:



(1) Water chiller - installation instructions

3.1.1 Installation Instructions

Provide manufacturer's standard catalog data, at least 5 weeks prior to the purchase or installation of a particular component, highlighted to show features such as materials, dimensions, options, performance and efficiency. Data must include manufacturer's recommended installation instructions and procedures. Data must be adequate to demonstrate compliance with contract requirements.

3.1.2 Vibration Isolation

If vibration isolation is specified for a unit, vibration isolator literature must be included containing catalog cuts and certification that the isolation characteristics of the isolators provided meet the manufacturer's recommendations.

3.1.3 Verification of Dimensions

Provide a letter including the date the site was visited, conformation of existing conditions, and any discrepancies found.

3.1.4 Certificates

Where the system, components, or equipment are specified to comply with requirements of AGA, NFPA, ARI, ASHRAE, ASME, or UL, proof of such compliance must be provided. The label or listing of the specified agency must be acceptable evidence. In lieu of the label or listing, a written certificate from an approved, nationally recognized testing organization equipped to perform such services, stating that the items have been tested and conform to the requirements and testing methods of the specified agency may be submitted. When performance requirements of this project's drawings and specifications vary from standard ARI rating conditions, computer printouts, catalog, or other application data certified by ARI or a nationally recognized laboratory as described above must be included. If ARI does not have a current certification program that encompasses such application data, the manufacturer may self certify that his application data complies with project performance requirements in accordance with the specified test standards.

3.1.5 Operation and Maintenance Manuals

Provide Six 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. Six 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.

3.1.6 Connections to Existing Systems

Notify the Contracting Officer in writing at least 15 calendar days prior

to the date the connections are required. Obtain approval before interrupting service. Furnish materials required to make connections into existing systems and perform excavating, backfilling, compacting, and other incidental labor as required. Furnish labor and tools for making actual connections to existing systems.

### 3.1.7 Refrigeration System

#### 3.1.7.1 Equipment

Refrigeration equipment and the installation thereof must conform to ANSI/ASHRAE 15 & 34. Necessary supports must be provided for all equipment, appurtenances, and pipe as required, including frames or supports for compressors, pumps, condensers, water coolers, and similar items. Compressors must be isolated from the building structure. If mechanical vibration isolators are not provided, vibration absorbing foundations must be provided. 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. Foundation drawings, bolt-setting information, and foundation bolts must be furnished 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.

#### 3.1.7.2 Field Refrigerant Charging

- a. Initial Charge: Upon completion of all the refrigerant pipe tests, the vacuum on the system must be broken by adding the required charge of dry refrigerant for which the system is designed, in accordance with the manufacturer's recommendations. Contractor must provide the complete charge of refrigerant in accordance with manufacturer's recommendations. Upon satisfactory completion of the system performance tests, any refrigerant that has been lost from the system must be replaced. After the system is fully operational, service valve seal caps and blanks over gauge points must be installed and tightened.
- b. 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 must be pumped into the system receiver or other suitable container. The refrigerant must not be discharged into the atmosphere.
- c. Contractor's Responsibility: The Contractor must, 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 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 specified requirements including material, labor, and refrigerant if the leak is the result of defective

equipment, material, or installation.

### 3.1.7.3 Oil Charging

Except for factory sealed units, two complete charges of lubricating oil for each compressor crankcase must be furnished. One charge must be used during the performance testing period, and upon the satisfactory completion of the tests, the oil must be drained and replaced with the second charge.

### 3.1.8 Mechanical Room Ventilation

Mechanical ventilation systems must be in accordance with Section 23 00 00 AIR SUPPLY DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM.

### 3.1.9 Field Applied Insulation

Field installed insulation must be as specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS, except as defined differently herein.

### 3.1.10 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 MANUFACTURER'S FIELD SERVICE

The services of a factory-trained representative must be provided for a minimum of four (4) normal 8 hour working days on site. The representative shall advise on the following:

#### a. Hermetic machines:

- (1) Testing hermetic water-chilling unit under pressure for refrigerant leaks; evacuation and dehydration of machine to an absolute pressure of not over 300 micrometers.
- (2) Charging the machine with refrigerant.
- (3) Starting the machine.

#### b. Open Machines:

- (1) Erection, alignment, testing, and dehydrating.
- (2) Charging the machine with refrigerant.
- (3) Starting the machine.

## 3.3 CLEANING AND ADJUSTING

Equipment must be wiped clean, with all traces of oil, dust, dirt, or paint spots removed. Provide temporary filters for all fans that are operated during construction. Perform and document that proper Indoor Air Quality During Construction procedures have been followed; this includes providing documentation showing that after construction ends, and prior to occupancy, new filters were provided and installed. 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. At least one week before the official equipment warranty start date, all condenser coils on air-cooled water chillers and split-system water chillers must be cleaned in accordance with the chiller manufacturer's instructions. This work covers two coil cleanings. The condenser coils must be cleaned with an approved coil cleaner by a service technician, factory trained by the chiller manufacturer. The condenser coil cleaner must not have any detrimental affect on the materials or protective coatings on the condenser coils. Testing, adjusting, and balancing must be as specified in Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC.

### 3.4 FIELD ACCEPTANCE TESTING

#### 3.4.1 Test Plans

- a. Manufacturer's Test Plans: Within 120 calendar days after contract award, submit the following plans:

(1) Water chiller - Field Acceptance Test Plan

Field acceptance test plans must be developed by the chiller manufacturer detailing recommended field test procedures for that particular type and size of equipment. Field acceptance test plans developed by the installing Contractor, or the equipment sales agency furnishing the equipment, will not be acceptable.

The Contracting Officer will review and approve the field acceptance test plan for each of the listed equipment prior to commencement of field testing of the equipment. The approved field acceptance tests of the chiller and subsequent test reporting.

- b. Coordinated testing: Indicate in each field acceptance test plan when work required by this section requires coordination with test work required by other specification sections. Furnish test procedures for the simultaneous or integrated testing of controls which interlock and interface with controls for the equipment provided under Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC Section 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.
- c. Prerequisite testing: Chillers for which performance testing is dependent upon the completion of the work covered by Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC must have that work completed as a prerequisite to testing work under this section. Indicate in each field acceptance test plan when such prerequisite work is required.
- d. Test procedure: Indicate in each field acceptance test plan each equipment manufacturers published installation, start-up, and field acceptance test procedures. Include in each test plan a detailed step-by-step procedure for testing automatic controls provided by the manufacturer.

Each test plan must include the required test reporting forms to be completed by the Contractor's testing representatives. Procedures must be structured to test the controls through all modes of control to confirm that the controls are performing with the intended sequence of control.

Controller must be verified to be properly calibrated and have the proper set point to provide stable control of their respective equipment.

- e. Performance variables: Each test plan must list performance variables that are required to be measured or tested as part of the field test.

Include in the listed variables performance requirements indicated on the equipment schedules on the design drawings. Chiller manufacturer must furnish with each test procedure a description of acceptable results that have been verified.

Chiller manufacturer must identify the acceptable limits or tolerance within which each tested performance variable must acceptably operate.

- f. Job specific: Each test plan must be job specific and must address the particular cooling towers and particular conditions which exist in this contract. Generic or general preprinted test procedures are not acceptable.
- g. Specialized components: Each test plan must include procedures for field testing and field adjusting specialized components, such as hot gas bypass control valves, or pressure valves.

#### 3.4.2 Testing

- a. Each water chiller system must be field acceptance tested in compliance with its approved field acceptance test plan and the resulting following field acceptance test report submitted for approval:
  - (1) Water chiller - Field Acceptance Test Report
- b. Manufacturer's recommended testing: Conduct the manufacturer's recommended field testing in compliance with the approved test plan. Furnish a factory trained field representative authorized by and to represent the equipment manufacturer at the complete execution of the field acceptance testing.
- c. Operational test: Conduct a continuous 24 hour operational test for each item of equipment. Equipment shutdown before the test period is completed shall result in the test period being started again and run for the required duration. For the duration of the test period, compile an operational log of each item of equipment. Log required entries every two hours. Use the test report forms for logging the operational variables.
- d. Notice of tests: Conduct the manufacturer's recommended tests and the operational tests; record the required data using the approved reporting forms. Notify the Contracting Officer in writing at least 15 calendar days prior to the testing. Within 30 calendar days after acceptable completion of testing, submit each test report for review

and approval.

- e. Report forms: Type data entries and writing on the test report forms. Completed test report forms for each item of equipment must be reviewed, approved, and signed by the Contractor's test director. The manufacturer's field test representative must review, approve, and sign the report of the manufacturer's recommended test. Signatures must be accompanied by the person's name typed.
- f. Deficiency resolution: The test requirements acceptably met; deficiencies identified during the tests must be corrected in compliance with the manufacturer's recommendations and corrections retested in order to verify compliance.

### 3.5 SYSTEM PERFORMANCE TESTS

Six copies of the report must be provided in bound 8 1/2 by 11 inch booklets.

#### 3.5.1 General Requirements

Before each refrigeration system is accepted, tests to demonstrate the general operating characteristics of all equipment must be conducted by the manufacturer's approved start-up representative experienced in system start-up and testing, at such times as directed. 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. Corrections and adjustments must be made as necessary and tests must be re-conducted to demonstrate that the entire system is functioning as specified. Prior to acceptance, service valve seal caps and blanks over gauge points must be installed and tightened. Any refrigerant lost during the system startup must be replaced. If tests do not demonstrate satisfactory system performance, deficiencies must be corrected and the system must be retested. Tests must be conducted in the presence of the Contracting Officer. Water and electricity required for the tests will be furnished by the Government. Any material, equipment, instruments, and personnel required for the test must be provided by the Contractor. Field tests must be coordinated with Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC.

#### 3.5.2 Test Report

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. The report must also include the following information and must be taken at least three different times at outside dry-bulb temperatures that are at least 5 degrees F apart:

- a. Date and outside weather conditions.
- b. The load on the system based on the following:
  - (1) The refrigerant used in the system.
  - (2) Condensing temperature and pressure.
  - (3) Suction temperature and pressure.
  - (4) Running current, voltage and proper phase sequence for each phase of all motors.
  - (5) The actual on-site setting of all operating and safety controls.

- (6) Chilled water pressure, flow and temperature in and out of the chiller.
- (7) The position of the capacity-reduction gear at machine off, one-third loaded, one-half loaded, two-thirds loaded, and fully loaded.

### 3.6 DEMONSTRATIONS

Contractor must conduct a training course for the operating staff as designated by the Contracting Officer. The training period must consist of a total 16 hours of normal working time and start after the system is functionally completed but prior to final acceptance tests. The training course must cover all of the items contained in the approved operation and maintenance manuals as well as demonstrations of routine maintenance operations.

Provide 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.

-- End of Section --

SECTION 23 64 26

CHILLED WATER PIPING SYSTEMS

08/09

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

AMERICAN SOCIETY OF SANITARY ENGINEERING (ASSE)

ASSE 1003 (2009) Performance Requirements for Water Pressure Reducing Valves for Domestic Water Distribution Systems - (ANSI approved 2010)

ASSE 1017 (2009) Performance Requirements for Temperature Actuated Mixing Valves for Hot Water Distribution Systems - (ANSI approved 2010)

AMERICAN WELDING SOCIETY (AWS)

AWS A5.8/A5.8M (2019) Specification for Filler Metals 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 (2012) Safety in Welding and Cutting and Allied Processes

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 B16.11 (2016) Forged Fittings, Socket-Welding and Threaded

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 B16.26	(2013) Standard for Cast Copper Alloy Fittings for Flared Copper Tubes
ASME B16.3	(2021) Malleable Iron Threaded Fittings, Classes 150 and 300
ASME B16.39	(2014) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300
ASME B16.9	(2012) Standard for Factory-Made Wrought Steel Buttwelding Fittings
ASME B31.9	(2014) Building Services Piping
ASME B40.100	(2013) Pressure Gauges and Gauge Attachments
ASME BPVC SEC IX	(2017; Errata 2018) BPVC Section IX-Welding, Brazing and Fusing Qualifications

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 A733	(2016; R 2022) Standard Specification for Welded and Seamless Carbon Steel and Austenitic Stainless Steel Pipe Nipples
ASTM B117	(2019) Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM B32	(2020) Standard Specification for Solder Metal
ASTM B42	(2015a) Standard Specification for Seamless Copper Pipe, Standard Sizes
ASTM B62	(2015) Standard Specification for Composition Bronze or Ounce Metal Castings
ASTM B75/B75M	(2011) Standard Specification for Seamless Copper Tube
ASTM B813	(2016) Standard Specification for Liquid and Paste Fluxes for Soldering of Copper

and Copper Alloy Tube

ASTM B88	(2016) Standard Specification for Seamless Copper Water Tube
ASTM D3308	(2012) PTFE Resin Skived Tape
ASTM D520	(2000; R 2011) Zinc Dust Pigment
ASTM E84	(2023) Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM F1007	(1986; R 2014) Pipeline Expansion Joints of the Packed Slip Type for Marine Application
ASTM F1199	(1988; R 2015) Cast (All Temperatures and Pressures) and Welded Pipe Line Strainers (150 psig and 150 degrees F Maximum)

EXPANSION JOINT MANUFACTURERS ASSOCIATION (EJMA)

EJMA Stds	(2011) EJMA Standards
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HYDRAULIC INSTITUTE (HI)

HI 1.1-1.2	(2014) Rotodynamic (Centrifugal) Pump for Nomenclature and Definitions
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MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-110	(2010) Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends
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	(2011) Butterfly Valves
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-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 (2013) Bronze Gate, Globe, Angle and Check Valves

MSS SP-85 (2011) Gray Iron Globe & Angle Valves Flanged and Threaded Ends

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

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 90A (2021) Standard for the Installation of Air Conditioning and Ventilating Systems

1.2 SYSTEM DESCRIPTION

Provide the water systems having the minimum service (design) temperature-pressure rating indicated. Provision of the piping systems, including materials, installation, workmanship, fabrication, assembly, erection, examination, inspection, and testing shall be in accordance with the required and advisory provisions of ASME B31.9 except as modified or supplemented by this specification section or design drawings. This specification section covers the water systems piping which is located within, on, and adjacent to building(s) within the building(s) 5 foot line.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. 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

Calibrated Balancing Valves; G

Automatic Flow Control Valves; G

Water Temperature Mixing Valve; G

Water Temperature Regulating Valves; G

Water Pressure Reducing Valve; G

Pressure Relief Valve; G

Combination Pressure and Temperature Relief Valves; G

Expansion Joints; G

Pumps; G

Combination Strainer and Pump Suction Diffuser; G

Expansion Tanks; G

Air Separator Tanks; G

Water Treatment Systems; G

Proposed water treatment plan including a layout, control scheme, a list of existing make-up water conditions including the items listed in paragraph "WATER ANALYSIS", a list of chemicals, the proportion of chemicals to be added, the final treated water conditions, and a description of environmental concerns for handling the chemicals.

#### SD-06 Test Reports

Piping Welds NDE Report; G

Pressure Tests Reports; G

Report shall be provided in bound 8-1/2 by 11 inch booklets. In the reports, document all phases of the tests performed. Include initial test summaries, all repairs/adjustments made, and the final test results.

#### SD-07 Certificates

Employer's Record Documents (For Welding); G

Welding Procedures and Qualifications; G

#### SD-08 Manufacturer's Instructions

Lesson plan for the Instruction Course; G

#### SD-10 Operation and Maintenance Data; G

Requirements for data packages are specified Section 01 78 23 OPERATION AND MAINTENANCE DATA, except as supplemented and modified by this specification section.

Submit spare parts data for each different item of equipment specified, with operation and maintenance data packages. 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.

Submit a list of qualified permanent service organizations with operation and maintenance data packages. Include service organization addresses and service area or expertise. The service organizations shall 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.

Water Treatment Systems; G

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.  
Include testing procedures used in determining water quality.

A maintenance manual in bound 8-1/2 by 11 inch booklets listing routine maintenance procedures, possible breakdowns and repairs, and a trouble shooting guide.

Calibrated Balancing Valves, Data Package 3; G

Automatic Flow Control Valves, Data Package 3; G

Water Temperature Mixing Valve, Data Package 3; G

Water Temperature Regulating Valves, Data Package 3; G

Water Pressure Reducing Valve, Data Package 3; G

Pressure Relief Valve, Data Package 2; G

Combination Pressure and Temperature Relief Valves, Data Package 2; G

Expansion Joints, Data Package 2; G

Pumps, Data Package 3; G

Combination Strainer and Pump Suction Diffuser, Data Package 2; G

Expansion Tanks, Data Package 2; G

Air Separator Tanks, Data Package 2; G

#### 1.4 MODIFICATIONS TO 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.

##### 1.4.1 Definitions

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

##### 1.4.2 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, shall be

applied appropriately by the Contracting Officer as authorized by his administrative cognizance and the FAR.

#### 1.5 SAFETY REQUIREMENTS

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 shall be insulated, fully enclosed, guarded, or fitted with other types of safety devices. Safety devices shall be installed so that proper operation of equipment is not impaired.

#### 1.6 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 shall be the Contractor's responsibility. Any materials found to be damaged shall be replaced at the Contractor's expense. During installation, cap piping and similar openings to keep out dirt and other foreign matter. Any porous materials found to be contaminated with mold or mildew will be replaced at the Contractor's expense. Non-porous materials found to be contaminated with mold or mildew will be disinfected and cleaned prior to installation.

#### 1.7 PROJECT/SITE CONDITIONS

##### 1.7.1 Verification of Dimensions

The Contractor shall become 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.

##### 1.7.2 Drawings

Because of the small scale of the drawings, it is not possible to indicate all offsets, fittings, and accessories that may be required. The Contractor shall carefully investigate the plumbing, fire protection, electrical, structural and finish conditions that would affect the work to be performed and shall arrange such work accordingly, furnishing required offsets, fittings, and accessories to meet such conditions.

##### 1.7.3 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 STANDARD COMMERCIAL PRODUCTS

Materials and equipment shall be 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 shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening.

The two year use shall include applications of equipment and materials under similar circumstances and of similar size. The 2 years experience

shall 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 shall 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. System components shall be environmentally suitable for the indicated locations.

The equipment items shall be supported by service organizations. These service organizations shall 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.

## 2.2 STEEL PIPING

Chilled water piping shall be steel pipe or copper tubing. Provide steel piping with a ANSI/ASME Class 125 service rating, which for 150 degrees F, the pressure rating is 175 psig.

### 2.2.1 Pipe

Steel pipe, conform to ASTM A53/A53M, Schedule 40, Type E or S, Grades A or B. Do not use Type F pipe.

### 2.2.2 Fittings and End Connections (Joints)

Piping and fittings 1 inch and smaller shall have threaded connections. Piping and fittings larger than 1 inch and smaller than 3 inches shall have either threaded, or welded connections. Piping and fittings 3 inches and larger shall have welded, or flanged connections. The manufacturer of each fitting shall be permanently identified on the body of the fitting in accordance with MSS SP-25.

#### 2.2.2.1 Threaded Connections

Use threaded valves and pipe connections conforming to ASME B1.20.1. Used threaded fitting conforming to ASME B16.3. Use threaded unions conforming to ASME B16.39. Use threaded pipe nipples conforming to ASTM A733.

#### 2.2.2.2 Flanged Connections

Flanges shall conform to ASME B16.1, Class 125. Gaskets shall be nonasbestos compressed material in accordance with ASME B16.21, 1/16 inch thickness, full face or self-centering flat ring type. These gaskets shall contain aramid fibers bonded with styrene butadiene rubber (SBR) or nitrile butadiene rubber (NBR). Bolts, nuts, and bolt patterns shall conform to ASME B16.1.

#### 2.2.2.3 Welded Connections

Welded valves and pipe connections (both butt-welds and socket-welds types) shall conform to ASME B31.9. Butt-welded fittings shall conform to ASME B16.9. Socket-welded fittings shall conform to ASME B16.11. Welded fittings shall be identified with the appropriate grade and marking symbol.

#### 2.2.2.4 Dielectric Waterways and Flanges

Provide dielectric waterways with a water impervious insulation barrier capable of limiting galvanic current to 1 percent of short circuit current in a corresponding bimetallic joint. When dry, insulation barrier shall be able to withstand a 600-volt breakdown test. Provide dielectric waterways constructed of galvanized steel and have threaded end connections to match connecting piping. Dielectric waterways shall be suitable for the required operating pressures and temperatures. Provide dielectric flanges with the same pressure ratings as standard flanges and provide complete electrical isolation between connecting pipe and/or equipment as described herein for dielectric waterways.

### 2.3 COPPER TUBING

Provide copper tubing and fittings with a ANSI/ASME Class 125 service rating, which for 150 degrees F., the pressure rating is 175 psig.

#### 2.3.1 Tube

Use copper tube conforming to ASTM B88, Type L or M for aboveground tubing, and Type K for buried tubing.

#### 2.3.2 Fittings and End Connections (Solder and Flared Joints)

Wrought copper and bronze solder joint pressure fittings, including unions and flanges, shall conform to ASME B16.22 and ASTM B75/B75M. Provide adapters as required. Cast copper alloy solder-joint pressure fittings, including unions and flanges, shall conform to ASME B16.18. Cast copper alloy fittings for flared copper tube shall conform to ASME B16.26 and ASTM B62. ASTM B42 copper pipe nipples with threaded end connections shall conform to ASTM B42.

Copper tubing of sizes larger than 4 inches shall have 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.

Extracted brazed tee joints may be used if produced with an acceptable tool and installed in accordance with tool manufacturer's written procedures.

#### 2.3.3 Solder

Provide solder in conformance with ASTM B32, grade Sb5, tin-antimony alloy. Solder flux shall be liquid or paste form, non-corrosive and conform to ASTM B813.

#### 2.3.4 Brazing Filler Metal

Filler metal shall conform to AWS A5.8/A5.8M, Type BAg-5 with AWS Type 3 flux, except Type BCuP-5 or BCuP-6 may be used for brazing copper-to-copper joints.

### 2.4 VALVES

Provide valves with a ANSI/ASME Class 125 service rating, which for 150 degrees F, the pressure rating is 175 psig.



#### 2.4.1 Globe and Angle Valve

Globe and angle valves 2-1/2 inches and smaller shall conform to MSS SP-80, Class 125. Globe and angle valves 3 inches and larger shall conform to MSS SP-85, Class 125.

#### 2.4.2 Check Valve

Check valves 2-1/2 inches and smaller shall conform to MSS SP-80. Check valves 3 inches and larger shall conform to MSS SP-71, Class 125.

#### 2.4.3 Butterfly Valve

Butterfly valves shall conform to MSS SP-67, Type 1 and shall be lug type. Valves smaller than 8 inches shall have throttling handles with a minimum of seven locking positions. Valves 8 inches and larger shall have totally enclosed manual gear operators with adjustable balance return stops and position indicators.

#### 2.4.4 Plug Valve

Plug valves 2 inches and larger shall conform to MSS SP-78, have flanged or threaded ends, and have cast iron bodies with bronze trim. Valves 2 inches and smaller shall be bronze with NPT connections for black steel pipe and brazed connections for copper tubing. Valve shall be lubricated, non-lubricated, or tetrafluoroethylene resin-coated type. Valve shall be resilient, double seated, trunnion mounted with tapered lift plug capable of 2-way shutoff. Valve shall operate from fully open to fully closed by rotation of the handwheel to lift and turn the plug. Valves 8 inches or larger shall be provided with manual gear operators with position indicators.

#### 2.4.5 Ball Valve

Full port design. Ball valves 1/2 inch and larger shall conform to MSS SP-72 or MSS SP-110 and shall be cast iron or bronze with threaded, soldered, or flanged ends. Valves 8 inches or larger shall be provided with manual gear operators with position indicators. Ball valves may be provided in lieu of gate valves.

#### 2.4.6 Square Head Cocks

Provide copper alloy or cast-iron body with copper alloy plugs, suitable for 125 psig water working pressure.

#### 2.4.7 Calibrated Balancing Valves

Copper alloy or cast iron body, copper alloy or stainless internal working parts. Provide valve calibrated so that flow can be determined when the temperature and pressure differential across valve is known. Valve shall have an integral pointer which registers the degree of valve opening. Valve shall function as a service valve when in fully closed position. Valve shall be constructed with internal seals to prevent leakage and shall be supplied with preformed insulation.

Provide valve bodies with tapped openings and pipe extensions with positive shutoff valves outside of pipe insulation. The pipe extensions shall be provided with quick connecting hose fittings for a portable differential pressure meter connections to verify the pressure differential. Provide metal tag on each valve showing the gallons per

minute flow for each differential pressure reading.

#### 2.4.8 Automatic Flow Control Valves

Valve shall automatically maintain the constant flow indicated on the design drawings. Valve shall modulate by sensing the pressure differential across the valve body. Valve shall be selected for the flow required and provided with a permanent nameplate or tag carrying a permanent record of the factory-determined flow rate and flow control pressure levels. Provide valve that controls the flow within 5 percent of the tag rating. Valve materials shall be the same as specified for the ball or plug valves.

Provide valve that are the type as indicated. Valve shall be capable of positive shutoff against the system pump head, valve bodies shall be provided with tapped openings and pipe extensions with shutoff valves outside of pipe insulation. The pipe extensions shall be provided with quick connecting hose fittings and differential meter, suitable for the operating pressure specified. Provide the meter complete with hoses, vent, integral metering connections, and carrying case as recommended by the valve manufacturer.

#### 2.4.9 Water Temperature Mixing Valve

Valve, ASSE 1017 for water service.

#### 2.4.10 Water Temperature Regulating Valves

Provide copper alloy body, direct acting, pilot operated, for the intended service.

#### 2.4.11 Water Pressure Reducing Valve

Valve, ASSE 1003 for water service, copper alloy body.

#### 2.4.12 Pressure Relief Valve

Valve shall prevent excessive pressure in the piping system when the piping system reaches its maximum heat buildup. Valve, ANSI Z21.22/CSA 4.4 and shall have cast iron bodies with corrosion resistant internal working parts. The discharge pipe from the relief valve shall be the size of the valve outlet unless otherwise indicated.

#### 2.4.13 Combination Pressure and Temperature Relief Valves

ANSI Z21.22/CSA 4.4, copper alloy body, automatic re-seating, test lever, and discharge capacity based on AGA temperature steam rating.

#### 2.4.14 Drain Valves

Valves, MSS SP-80 gate valves. Valve shall be manually-operated, 3/4 inch pipe size and above with a threaded end connection. Provide valve with a water hose nipple adapter. Freeze-proof type valves shall be provided in installations exposed to freezing temperatures.

#### 2.4.15 Air Venting Valves

Manually-operated general service type air venting valves, brass or bronze valves that are furnished with threaded plugs or caps. Automatic type air

venting shall be the ball-float type with brass/bronze or brass bodies, 300 series corrosion-resistant steel float, linkage and removable seat. Air venting valves on water coils shall have not less than 1/8 inch threaded end connections. Air venting valves on water mains shall have not less than 3/4 inch threaded end connections. Air venting valves on all other applications shall have not less than 1/2 inch threaded end connections.

#### 2.4.16 Vacuum Relief Valves

ANSI Z21.22/CSA 4.4

#### 2.4.17 Chainwheels

Chainwheel valve activation assemblies shall include sprocket rim, chain guides, chain and attachment brackets for mounting chainwheels to hand wheels. Sprocket rim with chain guides shall be ductile or cast iron, of the type and size required for the valve. Include zinc or epoxy coating. chain shall be hot-dip, galvanized steel, of the size required to fit the sprocket rim.

### 2.5 PIPING ACCESSORIES

#### 2.5.1 Strainer

Strainer, ASTM F1199, except as modified and supplemented in this specification. Strainer shall be the cleanable, basket or "Y" type, the same size as the pipeline. Strainer bodies shall be fabricated of cast iron with bottoms drilled, and tapped. Provide blowoff outlet with pipe nipple, gate valve, and discharge pipe nipple. The bodies shall have arrows clearly cast on the sides indicating the direction of flow.

Provide strainer with removable cover and sediment screen. The screen shall be made of minimum 22 gauge monel, with small perforations numbering not less than 400 per square inch to provide a net free area through the basket of at least 3.30 times that of the entering pipe. The flow shall be into the screen and out through the perforations.

#### 2.5.2 Combination Strainer and Pump Suction Diffuser

Angle type body with removable strainer basket and internal straightening vanes, a suction pipe support, and a blowdown outlet and plug. Strainer shall be in accordance with ASTM F1199, except as modified and supplemented by this specification. Unit body shall have arrows clearly cast on the sides indicating the direction of flow.

Strainer screen shall be made of minimum 22 gauge monel, with small perforations numbering not less than 400 per square inch to provide a net free area through the basket of at least 3.30 times that of the entering pipe. Flow shall be into the screen and out through the perforations. Provide an auxiliary disposable fine mesh strainer which shall be removed 30 days after start-up. Provide warning tag for operator indicating scheduled date for removal.

Casing shall have connection sizes to match pump suction and pipe sizes, and be provided with adjustable support foot or support foot boss to relieve piping strains at pump suction. Provide unit casing with blowdown port and plug. Provide a magnetic insert to remove debris from system.

### 2.5.3 Flexible Pipe Connectors

Provide flexible bronze or stainless steel piping connectors with single braid. Equip flanged assemblies with limit bolts to restrict maximum travel to the manufacturer's standard limits. Unless otherwise indicated, the length of the flexible connectors shall be as recommended by the manufacturer for the service intended. Internal sleeves or liners, compatible with circulating medium, shall be provided when recommended by the manufacturer. Provide covers to protect the bellows where indicated.

### 2.5.4 Pressure and Vacuum Gauges

Gauges, ASME B40.100 with throttling type needle valve or a pulsation dampener and shut-off valve. Provide gauges with 4.5 inch dial, brass or aluminum case, bronze tube, and siphon. Gauge shall have a range from 0 psig to approximately 1.5 times the maximum system working pressure. Each gauge range shall be selected so that at normal operating pressure, the needle is within the middle-third of the range.

### 2.5.5 Temperature Gauges

Temperature gauges, shall be the industrial duty type and be provided for the required temperature range. Provide gauges with fixed thread connection, dial face gasketed within the case; and an accuracy within 2 percent of scale range. Gauges shall have Fahrenheit scale in 2 degree graduations scale (black numbers) on a white face. The pointer shall be adjustable. Rigid stem type temperature gauges shall be provided in thermal wells located within 5 feet of the finished floor. Universal adjustable angle type or remote element type temperature gauges shall be provided in thermal wells located 5 to 7 feet above the finished floor or in locations indicated. Remote element type temperature gauges shall be provided in thermal wells located 7 feet above the finished floor or in locations indicated.

#### 2.5.5.1 Stem Cased-Glass

Stem cased-glass case shall be polished stainless steel or cast aluminum, 9 inches long, with clear acrylic lens, and non-mercury filled glass tube with indicating-fluid column.

#### 2.5.5.2 Bimetallic Dial

Bimetallic dial type case shall be not less than 3-1/2 inches, stainless steel, and shall be hermetically sealed with clear acrylic lens. Bimetallic element shall be silicone dampened and unit fitted with external calibrator adjustment.

#### 2.5.5.3 Liquid-, Solid-, and Vapor-Filled Dial

Liquid-, solid-, and vapor-filled dial type cases shall be not less than 3-1/2 inches, stainless steel or cast aluminum with clear acrylic lens. Fill shall be nonmercury, suitable for encountered cross-ambients, and connecting capillary tubing shall be double-braided bronze.

#### 2.5.5.4 Thermal Well

Thermal well shall 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 shall not be used in thermometers. Extended neck thermal wells shall be of sufficient length to clear insulation thickness by 1 inch.

#### 2.5.6 Pipe Hangers, Inserts, and Supports

Pipe hangers, inserts, guides, and supports: to MSS SP-58 and MSS SP-69.

#### 2.5.7 Escutcheons

Provide one piece or split hinge metal plates for piping entering floors, walls, and ceilings in exposed spaces. Secure plates in place by internal spring tension or set screws. 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.

#### 2.5.8 Expansion Joints

##### 2.5.8.1 Slip-Tube Type

Slip-tube expansion joints, ASTM F1007, Class I or II. Joints shall be provided with internally-externally alignment guides, injected semi-plastic packing, and service outlets. End connections shall be flanged or beveled for welding as indicated. Initial settings shall be made in accordance with the manufacturer's recommendations to compensate for ambient temperature at time of installation. Pipe alignment guides shall be installed as recommended by the joint manufacturer.

##### 2.5.8.2 Flexible Ball Type

Flexible ball expansion joints shall be capable of 360 degrees rotation plus 15 degrees angular flex movement. Joints shall be constructed of carbon steel with the exterior spherical surface of carbon steel balls plated with a minimum 5 mils of hard chrome in accordance with EJMA Stds. Joint end connections shall be threaded for piping 2 inches or smaller. Joint end connections larger than 2 inches shall be grooved, flanged, or beveled for welding. Provide joint with pressure-molded composition gaskets suitable for continuous operation at twice design temperature.

#### 2.5.9 Test Plugs

Refer to Section 23 52 00 HEATING BOILERS.

### 2.6 CHILLED WATER PUMPS

Chilled water pumps shall be the vertical, close couples, in-line electrically driven, non-overloading, centrifugal type which conform to HI 1.1-1.2. Pumps shall be selected at or within 5 percent of peak efficiency. Pump curve shall rise continuously from maximum capacity to shutoff. Pump motor shall be NEMA premium efficiency with Class F insulation, rated for inverter duty, conforming to the requirements of paragraph ELECTRICAL EQUIPMENT, and have sufficient horsepower for the service required. Pump/motor shall be provide with a packaged variable frequency or ECM drive conforming to the requirements of Section 26 29 23, ADJUSTABLE SPEED DRIVE (ASD) SYSTEMS UNDER 600 VOLTS where applicable. In addition, the chilled water pump variable frequency or ECM drives shall be configured to vary the output frequency based on a differential pressure signal from a remote differential pressure transmitter or utilize software resident in the VFD/ECM to provide automatic pump speed control without

the need for a pump or remote mounted differential pressure transmitter. Pump motor shall have the required capacity to prevent overloading with pump operating at any point on its characteristic curve. Pump speed shall not exceed 1,800 rpm.

#### 2.6.1 Construction

Each pump casing shall be designed to withstand the discharge head specified plus the static head on system plus 50 percent of the total, but not less than 125 psig. Pump casing and bearing housing shall be close grained cast iron. High points in the casing shall be provided with manual air vents; low points shall be provided with drain plugs. Provide threaded suction and discharge pressure gage tapping with square-head plugs.

Impeller shall be statically and dynamically balanced. Impeller, impeller wearing rings, glands, casing wear rings, and shaft sleeve shall be bronze. Shaft shall be carbon or alloy steel, turned and ground. Bearings shall be ball-bearings, roller-bearings, or oil-lubricated bronze-sleeve type bearings, and be efficiently sealed or isolated to prevent loss of oil or entrance of dirt or water.

Chilled water pumps shall be vertical split coupled in-line centrifugal pumps. Shaft seals shall be mechanical-seals box type.

#### 2.6.2 Mechanical Shaft Seals

Seals shall be single, inside mounted, end-face-elastomer bellows type with stainless steel spring, brass or stainless steel seal head, carbon rotating face, and tungsten carbide or ceramic sealing face. Glands shall be bronze and of the water-flush design to provide lubrication flush across the face of the seal. Bypass line from pump discharge to flush connection in gland shall be provided, with filter or cyclone particle separator in line.

#### 2.7 EXPANSION TANKS

Tank shall be welded steel, constructed for, and tested to the requirements of ASME Section VIII, Division 1 with a pressure-temperature rating of 125 psi at 150 degrees F. Provide tanks precharged to the minimum operating pressure. Tank shall have a replaceable heavy duty, Butyl rubber bladder.

Tanks shall accommodate expanded water of the system generated within the normal operating temperature range, limiting this pressure increase at all components in the system to the maximum allowable pressure at those components. Each tank air chamber shall be fitted with a drain, fill, an air charging valve, and system connections. Tank shall be supported by steel legs or bases for vertical installation or steel saddles for horizontal installations. The only air in the system shall be the permanent sealed-in air cushion contained within the expansion tank.

#### 2.8 AIR SEPARATOR TANKS

Design to separate air from water and to direct released air to automatic air vent. Unit shall be of carbon steel construction with internal baffles and two air chambers at top of unit; one air chamber shall have outlet to expansion tank and other air chamber shall be provided with automatic air release device. Tank shall be steel, constructed for, and

tested to a ANSI Class 125 pressure-temperature rating in accordance with ASME Code Section VIII, division 1.

## 2.9 WATER TREATMENT SYSTEMS

When water treatment is specified, the use of chemical-treatment products containing equivalent chromium (CPR) is prohibited.

### 2.9.1 Water Analysis

Refer to Section 23 52 00 HEATING BOILERS for Contractor-furnished water analysis.

### 2.9.2 Chilled Water

Water to be used in the chilled water system shall be treated to maintain the conditions recommended by this specification as well as the recommendations from the manufacturers of the evaporator coils. Chemicals shall meet all required federal, state, and local environmental regulations for the treatment of evaporator coils and direct discharge to the sanitary sewer.

### 2.9.3 Chilled Water System

A shot feeder shall be provided on the chilled water piping as indicated. Size and capacity of feeder shall be based on local requirements and water analysis. The feeder shall be furnished with an air vent, gauge glass, funnel, valves, fittings, and piping.

## 2.10 ELECTRICAL WORK

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. 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, shall be provided. For packaged equipment, the manufacturer shall provide controllers including the required monitors and timed restart.

Provide high efficiency type, single-phase, fractional-horsepower alternating-current motors, including motors that are part of a system, in accordance with NEMA MG 11.

Provide polyphase, squirrel-cage medium induction motors, 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.

Motors shall be rated for continuous duty with the enclosure specified. Motor duty requirements shall allow for maximum frequency start-stop operation and minimum encountered interval between start and stop. Motor torque shall 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. Provide motor starters complete with thermal overload protection and other necessary appurtenances. Motor bearings shall be fitted with grease supply fittings and grease relief to outside

of the enclosure.

Where two-speed or variable-speed motors are indicated, solid-state variable-speed controllers may be provided 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.

## 2.11 PAINTING OF NEW EQUIPMENT

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

### 2.11.1 Factory Painting Systems

Manufacturer's standard factory painting systems may be provided. The factory painting system applied will withstand 125 hours in a salt-spray fog test, except that equipment located outdoors shall withstand 500 hours in a salt-spray fog test.

Salt-spray fog test shall be in accordance with ASTM B117, and for that test, the acceptance criteria shall be as follows: immediately after completion of the test, the paint shall show no signs of blistering, wrinkling, or cracking, and no loss of 0.125 inch on either side of the scratch mark. The film thickness of the factory painting system applied on the equipment shall 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 shall be designed for the temperature service.

### 2.11.2 Shop Painting Systems for Metal Surfaces

Clean, retreat, 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 shall be cleaned to bare metal.

Where hot-dip galvanized steel has been cut, resulting surfaces with no galvanizing shall be coated with a zinc-rich coating conforming to ASTM D520, Type I.

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 shall 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 shall 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 shall 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 shall receive two coats of 600 degrees F heat-resisting paint applied to a total minimum dry film thickness of 2 mils.

## 2.12 FACTORY APPLIED INSULATION

Factory insulated items installed outdoors are not required to be fire-rated. As a minimum, factory insulated items installed indoors shall have a flame spread index no higher than 25 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 shall have a flame spread index no higher than 25 and a smoke developed index no higher than 50. Flame spread and smoke developed indexes shall be determined by ASTM E84.

Insulation shall 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 shall be tested as a composite material. Jackets, facings, and adhesives shall 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.

## 2.13 NAMEPLATES

Major equipment including pumps, pump motors, expansion tanks, and air separator tanks shall have the manufacturer's name, type or style, model or serial number on a plate secured to the item of equipment. The nameplate of the distributing agent will not be acceptable. Plates shall be durable nickel-copper, 304 stainless steel, monel or other Government approved non-corroding metal. Plates shall be fixed in prominent locations with nonferrous screws or bolts.

## 2.14 RELATED COMPONENTS/SERVICES

### 2.14.1 Drain and Make-Up Water Piping

Requirements for drain and make-up water piping and backflow preventer is specified in Section 22 00 00 PLUMBING, GENERAL PURPOSE.

### 2.14.2 Cathodic Protection

Requirements for cathodic protection systems is specified in Section 26 42 14.00 10 CATHODIC PROTECTION SYSTEM (SACRIFICIAL ANODE)Section

### 2.14.3 Field Applied Insulation

Requirements for field installed insulation is specified in Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS, except as supplemented and modified by this specification section.

### 2.14.4 Field Painting

Requirements for painting of surfaces not otherwise specified, and finish painting of items only primed at the factory, are specified in Section 09 90 00PAINTS AND COATINGS.

#### 2.14.4.1 Color Coding

Requirements for color coding for piping identification are specified in Section 09 90 00 PAINTS AND COATINGS.

#### 2.14.5 Vibration Control and Seismic Protection

Requirements for vibration control and seismic protection are specified in Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT and Section 23 05 48.19 SEISMIC BRACING FOR HVAC.

### PART 3 EXECUTION

#### 3.1 INSTALLATION

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 burrs by reaming, and fashion to permit free expansion and contraction without causing damage to the building structure, pipe, joints, or hangers.

Notify the Contracting Officer in writing at least 15 calendar days prior to the date the connections are required. Obtain approval before interrupting service. Furnish materials required to make connections into existing systems and perform excavating, backfilling, compacting, and other incidental labor as required. Furnish labor and tools for making actual connections to existing systems.

##### 3.1.1 Pipe Flushing

a. A proper flushing plan is the responsibility of the Contractor and includes the following:

1. Adequate flushing taps to promote sufficient flow velocity detailed herein.
2. Means of circulating flow whether a rental pump or system pump. Consult the Contracting Officer or Architect/Engineer if a system pump is to be used. Obtain a letter from the pump manufacturer confirming no warranties will be voided.
3. Start-up strainers should be inserted into pumps with a 40-micro mesh if not provided by pump manufacturer.

b. The flushing plan, including tap location drawing, shall be submitted to the Contracting Officer and/or Architect/Engineer for approval prior to commencement.

c. Flush the system with clean water. Remove, clean, and replace any strainer screens throughout the flushing process to ensure no plugging occurs.

d. Flushing should occur with enough flow to achieve 10 feet per second (or maximum possible) to lift and flush debris. System should be flushed until clear water is observed for a minimum of 2 hours.

e. Do not flush through major equipment (i.e. chillers, boilers, heat

exchangers, cooling towers, etc.) Install means to jumper around this equipment.

f. Post flushing, for cleaning passivation, circulate cleaning chemicals at a reduced velocity between 3 and 6 feet per second. Flush until alkalinity is below 30 ppm and iron less than 2 ppm as determined by a water analysis. Consult water treatment Contractor for chemical injection.

g. Drain at all system low points (drip legs, etc.) when flushing is complete.

h. Remove start-up strainers and insert normal operating strainers.

i. If system will be dry for any period of time, charge the piping with nitrogen to 5 PSIG to prevent rusting.

### 3.1.2 Welding

Provide welding work specified this section for piping systems in conformance with ASME B31.9, as modified and supplemented by this specification section and the accompanying drawings. The welding work includes: qualification of welding procedures, welders, welding operators, brazers, brazing operators, and nondestructive examination personnel; maintenance of welding records, and examination methods for welds.

#### 3.1.2.1 Employer's Record Documents (For Welding)

Submit for review and approval the following documentation. This documentation and the subject qualifications shall be in compliance with ASME B31.9.

- 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 examination personnel that are proposed to be used to provide the work specified in this specification section.

#### 3.1.2.2 Welding Procedures and Qualifications

- a. Specifications and Test Results: Submit copies of the welding procedures 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.
- b. 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 shall 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.

### 3.1.2.3 Examination of Piping Welds

Conduct non-destructive examinations (NDE) on piping welds and brazing and verify the work meets the acceptance criteria specified in ASME B31.9. NDE on piping welds covered by ASME B31.9 is visual inspection only. Submit a Piping Welds NDE Report meeting the requirements specified in ASME B31.9.

### 3.1.2.4 Welding Safety

Welding and cutting safety requirements shall be in accordance with AWS Z49.1.

### 3.1.3 Directional Changes

Make changes in direction with fittings, except that bending of pipe 1 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 shall not be less than 6 diameters of the pipe. Bent pipe showing kinks, wrinkles, flattening, or other malformations is not acceptable.

### 3.1.4 Functional Requirements

Pitch horizontal supply mains down in the direction of flow as indicated. The grade shall not be less than 1 inch in 40 feet. Reducing fittings shall be used for changes in pipe sizes. Cap or plug open ends of pipelines and equipment during installation to keep dirt or other foreign materials out of the system.

Pipe not otherwise specified shall be uncoated. Connections to appliances shall be made with malleable iron unions for steel pipe 2-1/2 inches or less in diameter, and with flanges for pipe 3 inches and above in diameter. Connections between ferrous and copper piping shall be electrically isolated from each other with dielectric waterways or flanges.

Piping located in air plenums shall conform to NFPA 90A requirements. Pipe and fittings installed in inaccessible conduits or trenches under concrete floor slabs shall be welded. Equipment and piping arrangements shall fit into space allotted and allow adequate acceptable clearances for installation, replacement, entry, servicing, and maintenance. Electric isolation fittings shall be provided between dissimilar metals.

### 3.1.5 Fittings and End Connections

#### 3.1.5.1 Threaded Connections

Threaded connections shall be made with tapered threads and made tight with PTFE tape complying with ASTM D3308 or equivalent thread-joint compound applied to the male threads only. Not more than three threads shall show after the joint is made.

#### 3.1.5.2 Brazed Connections

Brazing, AWS BRH, except as modified herein. During brazing, the pipe and fittings shall be filled with a pressure regulated inert gas, such as nitrogen, to prevent the formation of scale. Before brazing copper

joints, both the outside of the tube and the inside of the fitting shall be cleaned with a wire fitting brush until the entire joint surface is bright and clean. Do not use brazing flux. Surplus brazing material shall be removed at all joints. Steel tubing joints shall be made in accordance with the manufacturer's recommendations. Piping shall be supported prior to brazing and not be sprung or forced.

#### 3.1.5.3 Welded Connections

Branch connections shall be made with welding tees or forged welding branch outlets. Pipe shall be thoroughly cleaned of all scale and foreign matter before the piping is assembled. During welding, the pipe and fittings shall be filled with an inert gas, such as nitrogen, to prevent the formation of scale. Beveling, alignment, heat treatment, and inspection of weld shall conform to ASME B31.9. Weld defects shall be removed and rewelded at no additional cost to the Government. Electrodes shall be stored and dried in accordance with AWS D1.1/D1.1M or as recommended by the manufacturer. Electrodes that have been wetted or that have lost any of their coating shall not be used.

#### 3.1.5.4 Flared Connections

When flared connections are used, a suitable lubricant shall be used between the back of the flare and the nut in order to avoid tearing the flare while tightening the nut.

#### 3.1.5.5 Flanges and Unions

Except where copper tubing is used, union or flanged joints shall be provided in each line immediately preceding the connection to each piece of equipment or material requiring maintenance such as coils, pumps, control valves, and other similar items. Flanged joints shall be assembled square end tight with matched flanges, gaskets, and bolts. Gaskets shall be suitable for the intended application.

#### 3.1.6 Valves

Isolation ball valves shall be installed on each side of each piece of equipment, at the midpoint of all looped mains, and at any other points indicated or required for draining, isolating, or sectionalizing purpose. Isolation valves may be omitted where balancing cocks are installed to provide both balancing and isolation functions. Each valve except check valves shall be identified. Valves in horizontal lines shall be installed with stems horizontal or above.

#### 3.1.7 Air Vents

Air vents shall be provided at all high points, on all water coils, and where indicated to ensure adequate venting of the piping system.

#### 3.1.8 Drains

Drains shall be provided at all low points and where indicated to ensure complete drainage of the piping. Drains shall be accessible, and shall consist of nipples and caps or plugged tees unless otherwise indicated.

#### 3.1.9 Flexible Pipe Connectors

Connectors shall be attached to components in strict accordance with the

latest printed instructions of the manufacturer to ensure a vapor tight joint. Hangers, when required to suspend the connectors, shall be of the type recommended by the flexible pipe connector manufacturer and shall be provided at the intervals recommended.

#### 3.1.10 Temperature Gauges

Temperature gauges shall be located on coolant supply and return piping at each heat exchanger, on condenser water piping entering and leaving a condenser, at each automatic temperature control device without an integral thermometer, and where indicated or required for proper operation of equipment. Thermal wells for insertion thermometers and thermostats shall extend beyond thermal insulation surface not less than 1 inch.

#### 3.1.11 Pipe Hangers, Inserts, and Supports

Pipe hangers, inserts, and supports shall conform to MSS SP-58 and MSS SP-69, except as supplemented and modified in this specification section. Pipe hanger types 5, 12, and 26 shall not be used. Hangers used to support piping 2 inches and larger shall be fabricated to permit adequate adjustment after erection while still supporting the load. Piping subjected to vertical movement, when operating temperatures exceed ambient temperatures, shall be supported by variable spring hangers and supports or by constant support hangers.

##### 3.1.11.1 Hangers

Type 3 shall not be used on insulated piping. Type 24 may be used only on trapeze hanger systems or on fabricated frames.

##### 3.1.11.2 Inserts

Type 18 inserts shall be secured 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.

##### 3.1.11.3 C-Clamps

Type 19 and 23 C-clamps shall be torqued per MSS SP-69 and have both locknuts and retaining devices, furnished by the manufacturer. Field-fabricated C-clamp bodies or retaining devices are not acceptable.

##### 3.1.11.4 Angle Attachments

Type 20 attachments used on angles and channels shall be furnished with an added malleable-iron heel plate or adapter.

##### 3.1.11.5 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, shall be used on all pipe 4 inches and larger when the temperature of the medium is 60 degrees F or higher. Type 40 shields shall be used on all piping less than 4 inches and all piping 4 inches and larger carrying medium less than 60 degrees F. A high density insulation insert of cellular glass shall be used under the Type 40 shield for piping 2 inches and larger.

#### 3.1.11.6 Horizontal Pipe Supports

Horizontal pipe supports shall be spaced as specified in MSS SP-69 and a support shall be installed not over 1 foot from the pipe fitting joint at each change in direction of the piping. Pipe supports shall be spaced not over 5 feet apart at valves. Pipe hanger loads suspended from steel joist with hanger loads between panel points in excess of 50 pounds shall have the excess hanger loads suspended from panel points.

#### 3.1.11.7 Vertical Pipe Supports

Vertical pipe shall be supported 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.

#### 3.1.11.8 Pipe Guides

Type 35 guides using, steel, reinforced polytetrafluoroethylene (PTFE) or graphite slides shall be provided where required to allow longitudinal pipe movement. Lateral restraints shall be provided as required. Slide materials shall be suitable for the system operating temperatures, atmospheric conditions, and bearing loads encountered.

#### 3.1.11.9 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, a Type 39 saddle shall be used. 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.

#### 3.1.11.10 Multiple Pipe Runs

In the support of multiple pipe runs on a common base member, a clip or clamp shall be used where each pipe crosses the base support member. Spacing of the base support members shall not exceed the hanger and support spacing required for an individual pipe in the multiple pipe run.

#### 3.1.11.11 Structural Attachments

Attachment to building structure concrete and masonry shall be by cast-in concrete inserts, built-in anchors, or masonry anchor devices. Inserts and anchors shall be applied with a safety factor not less than 5. Supports shall not be attached to metal decking. Supports shall not be attached to the underside of concrete filled floors or concrete roof decks unless approved by the Contracting Officer. Masonry anchors for overhead applications shall be constructed of ferrous materials only. Structural steel brackets required to support piping, headers, and equipment, but not shown, shall be provided under this section. Material used for support shall be as specified under Section 05 12 00 STRUCTURAL STEEL.

#### 3.1.12 Pipe Alignment Guides

Pipe alignment guides shall be provided 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.

### 3.1.13 Pipe Anchors

Anchors shall be provided where indicated. Unless indicated otherwise, anchors shall comply with the requirements specified. Anchors shall consist of heavy steel collars with lugs and bolts for clamping and attaching anchor braces, unless otherwise indicated. Anchor braces shall be installed in the most effective manner to secure the desired results using turnbuckles where required.

Supports, anchors, or stays shall not be attached 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, these items shall be anchored immediately adjacent to each penetrated surface, to provide essentially zero movement within penetration seal.

### 3.1.14 Building Surface Penetrations

Sleeves shall not be installed in structural members except where indicated or approved. Except as indicated otherwise piping sleeves shall comply with requirements specified. Sleeves in nonload bearing surfaces shall be galvanized sheet metal, conforming to ASTM A653/A653M, Coating Class G-90, 20 gauge. Sleeves in load bearing surfaces shall be uncoated carbon steel pipe, conforming to ASTM A53/A53M, Schedule 30. Sealants shall be applied to moisture and oil-free surfaces and elastomers to not less than 1/2 inch depth. Sleeves shall not be installed in structural members.

#### 3.1.14.1 General Service Areas

Each sleeve shall extend through its respective wall, floor, or roof, and shall be cut flush with each surface. Pipes passing through concrete or masonry wall or concrete floors or roofs shall be provided with pipe sleeves fitted into place at the time of construction. Sleeves shall be of such size as to provide 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, the annular space between pipe and sleeve or between jacket over-insulation and sleeve shall be sealed in accordance with Section 07 92 00 JOINT SEALANTS.

#### 3.1.14.2 Waterproof Penetrations

Pipes passing through roof or floor waterproofing membrane shall be installed through a .17 ounce copper sleeve, or a 0.032 inch thick aluminum sleeve, each within an integral skirt or flange.

Flashing sleeve shall be suitably formed, and skirt or flange shall extend not less than 8 inches from the pipe and be set over the roof or floor membrane in a troweled coating of bituminous cement. The flashing sleeve shall extend up the pipe a minimum of 2 inches above the roof or floor penetration. The annular space between the flashing sleeve and the bare pipe or between the flashing sleeve and the metal-jacket-covered insulation shall be sealed as indicated. Penetrations shall be sealed by either one of the following methods.

- a. 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.



Waterproofing membrane shall be clamped into place and sealant shall be placed in the caulking recess.

- b. Modular Mechanical Type Sealing Assembly: In lieu of a waterproofing clamping flange, a modular mechanical type sealing assembly may be installed. Seals shall consist 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. Links shall 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 shall cause the rubber sealing elements to expand and provide a watertight seal between the pipe/conduit and the sleeve. Each seal assembly shall be sized as recommended by the manufacturer to fit the pipe/conduit and sleeve involved. The Contractor electing to use the modular mechanical type seals shall provide sleeves of the proper diameters.

#### 3.1.14.3 Fire-Rated Penetrations

Penetration of fire-rated walls, partitions, and floors shall be sealed as specified in Section 07 84 00 FIRESTOPPING. Firestopping materials be furnished and installed by the Firestopping installer and shall conform to the requirements in Section 07 84 00 FIRESTOPPING.

#### 3.1.14.4 Escutcheons

Finished surfaces where exposed piping, bare or insulated, pass through floors, walls, or ceilings, except in boiler, utility, or equipment rooms, shall be provided with escutcheons. Where sleeves project slightly from floors, special deep-type escutcheons shall be used. Escutcheon shall be secured to pipe or pipe covering.

#### 3.1.15 Access Panels

Access panels shall be provided where indicated for all concealed valves, vents, controls, and additionally for items requiring inspection or maintenance. Access panels shall be of sufficient size and located so that the concealed items may be serviced and maintained or completely removed and replaced. Access panels shall be as specified in Section 05 50 13 MISCELLANEOUS METAL FABRICATIONS.

#### 3.1.16 Vibration Isolation

Provide vibration isolation equipment and material in accordance with the requirements on Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING EQUIPMENT and as indicated on the drawings.

#### 3.1.17 Chainwheels

Install chainwheels on operators for butterfly valves NPS 6 and larger and more than 96 inches above the floor. Extend chains to 72 inches above finished floor.

### 3.2 ELECTRICAL INSTALLATION

Install electrical equipment in accordance with NFPA 70 and manufacturers instructions.

### 3.3 CLEANING AND ADJUSTING

Pipes shall be cleaned free of scale and thoroughly flushed of all foreign matter. A temporary bypass shall be provided for all water coils to prevent flushing water from passing through coils. Strainers and valves shall be thoroughly cleaned. Prior to testing and balancing, air shall be removed from all water systems by operating the air vents. Temporary measures, such as piping the overflow from vents to a collecting vessel shall be taken to avoid water damage during the venting process. Air vents shall be plugged or capped after the system has been vented. Control valves and other miscellaneous equipment requiring adjustment shall be adjusted to setting indicated or directed.

### 3.4 FIELD TESTS

Field tests shall be conducted in the presence of the QC Manager or his designated representative to verify systems compliance with specifications. Any material, equipment, instruments, and personnel required for the test shall be provided by the Contractor.

#### 3.4.1 Equipment and Component Isolation

Prior to testing, equipment and components that cannot withstand the tests shall be properly isolated.

#### 3.4.2 Pressure Tests

Each piping system shall be hydrostatically tested at a pressure not less than 188 psig for period of time sufficient to inspect every joint in the system and in no case less than 2 hours. Test pressure shall be monitored by a currently calibrated test pressure gauge. Leaks shall be repaired and piping retested until test requirements are met. No leakage or reduction in gage pressure shall be allowed.

Leaks shall be repaired by rewelding or replacing pipe or fittings. Caulking of joints will not be permitted. Concealed and insulated piping shall be tested in place before concealing.

Submit for approval Pressure Tests Reports covering the above specified piping pressure tests; describe the systems tested, test results, defects found and repaired, and signature of the pressure tests' director. Obtain approval from the QC Manager before concealing piping or applying insulation to tested and accepted piping.

#### 3.4.3 Related Field Inspections and Testing

##### 3.4.3.1 Piping Welds

Examination of Piping Welds is specified in the paragraph EXAMINATION OF PIPING WELDS (above).

##### 3.4.3.2 HVAC TAB

Requirements for testing, adjusting, and balancing (TAB) of HVAC water

pipng, and associated equipment is specified in Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC. Coordinate with the TAB team, and provide support personnel and equipment as specified in Section 23 05 93 TESTING, ADJUSTING AND BALANCING FOR HVAC to assist TAB team to meet the TAB work requirements.

### 3.5 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 chilled water, piping system. Instructors shall be thoroughly familiar with all parts of the installation and shall be instructed in operating theory as well as practical operation and maintenance work. Submit a Lesson plan for the Instruction Course for approval. The lesson plan and instruction course shall be based on the approved operation and maintenance data and maintenance manuals.

Conduct a training course for the operating staff and maintenance staff selected by the Contracting Officer. Give the 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 shall be one man-day.. Use approximately half of the time for classroom instruction and the other time for instruction at the location of 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.

-- End of Section --

SECTION 23 81 23.00 20

COMPUTER ROOM AIR CONDITIONING UNITS

02/10

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 410 (2001; Addendum 1 2002; Addendum 2 2005; Addendum 3 2011) Forced-Circulation Air-Cooling and Air-Heating Coils

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

ANSI/ASHRAE 15 & 34 (2022) ANSI/ASHRAE Standard 15-Safety Standard for Refrigeration Systems and ANSI/ASHRAE Standard 34-Designation and Safety Classification of Refrigerants

ASHRAE 52.2 (2017) Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

ASHRAE 55 (2010) Thermal Environmental Conditions for Human Occupancy

ASHRAE 62.1 (2022) Ventilation for Acceptable Indoor Air Quality

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B31.1 (2022) Power Piping

ASME B31.5 (2016) Refrigeration Piping and Heat Transfer Components

ASTM INTERNATIONAL (ASTM)

ASTM D5864 (2011) Standard Test Method for Determining Aerobic Aquatic Biodegradation of Lubricants or Their Components

ASTM D6081 (1998; R 2014) Aquatic Toxicity Testing of Lubricants: Sample Preparation and Results Interpretation

ETL TESTING LABORATORIES (ETL)

ETL DLP (updated continuously) ETL Listed Mark Directory

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

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

NFPA 90A (2021) Standard for the Installation of  
Air Conditioning and Ventilating Systems

U.S. ARMY CORPS OF ENGINEERS (USACE)

EM 1110-2-1424 (2016) Engineering and Design --  
Lubricants and Hydraulic Fluids

UNDERWRITERS LABORATORIES (UL)

UL Elec Equip Dir (2011) Electrical Appliance and  
Utilization Equipment Directory

1.2 SYSTEM DESCRIPTION

Provide new computer room air conditioning units (CRACU) complete and ready for operation. Size equipment based on Design Manual CS from the Air Conditioning Contractors of America; do not oversize.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. Submittals with an "S" are for inclusion in the Sustainability Notebook, 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

Computer room air conditioning units; G

Space temperature control system drawings; G

Filters; G

SD-06 Test Reports

Field Test Schedule; G

Manufacturer's Field Test Plans; G

Field Test Reports; G

Aquatic Toxicity

SD-07 Certificates

Credentials of the Manufacturer's Field Test Representative; G

SD-08 Manufacturer's Instructions

Installation Manual for Each Type of CRAC

SD-10 Operation and Maintenance Data

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

Computer Room Air Conditioning Units, Data Package 4; G

SD-11 Closeout Submittals

Energy Efficient Equipment for Computer Room Air Conditioning Units;  
S

Indoor Air Quality During Construction; S

1.4 ENVIRONMENTAL REQUIREMENTS

For proper Indoor Environmental Quality, maintain positive pressure within the building. Ventilation shall 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 shall meet or exceed ASHRAE 55.

1.5 VIBRATION CONTROL AND SEISMIC PROTECTION

Requirements for vibration control and seismic protection are specified in Section 23 05 48.00 40 VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT.

PART 2 PRODUCTS

2.1 PRODUCT SUSTAINABILITY CRITERIA

For products in this section, where applicable and to extent allowed by performance criteria, provide and document the following:

2.1.1 Energy Efficient Equipment for Computer Room Air Conditioning Units

Provide computer room air conditioning units meeting the efficiency requirements as stated within this section and provide documentation in conformance with Section 01 33 29 SUSTAINABILITY REPORTING paragraph ENERGY EFFICIENT EQUIPMENT.

2.2 COMPUTER ROOM AIR CONDITIONING UNITS (CRAC) (CHILLED WATER COOLING COILS)(FLOOR MOUNTED, UPFLOW UNITS)

ANSI/ASHRAE 15 & 34. Provide self-contained units, designed, factory assembled, and factory tested. Unit shall be listed in UL Elec Equip Dir or ETL DLP for computer room application. Unit shall include cabinet and frame, fan section, filter section, chilled water coil, heating water, reheat coil, humidifier, controls, and, interconnecting piping internal to the CRAC unit. CRAC units shall be designed for horizontal installation suspended from structure or floor mounted upflow as scheduled on drawings.

2.2.1 Cabinet and Frame

2.2.1.1 Unit Cabinet

Unit frame shall be minimum 14 gage welded steel tubes or steel angles and shall be mill-galvanized or coated with an epoxy finish, or an approved

manufacturer's standard finish, if equivalent.

Exterior panels shall be furniture grade steel sheet, minimum of 20 gage, mill-galvanized or coated with a corrosion-inhibiting epoxy finish, or an approved equivalent finish. Mill galvanized sheet metal shall be coated with not less than 1.25 ounces of zinc per square foot of two-sided surface. Mill rolled structural steel shall be hot-dip galvanized or primed and painted. Cut edges, burns and scratches in hot-dip galvanized surfaces shall be coated with galvanizing repair coating.

Provide removable panel for access to controls without interrupting airflow. Panels shall be gasketed to prevent air leakage under system operating pressure and shall be removable for service access without the use of special tools. Condensate pans shall be minimum 22 gage Type 304 stainless steel, non-corroding, double-sloped, and shall be piped to drain.

Exterior surfaces of cabinets constructed of mill-galvanized steel shall be finished by the manufacturer's standard enamel finish in the specified color.

CRAC unit manufacturer's standard cabinet materials and finishes will be acceptable if considered equivalent to the above requirements by the Contracting Officer.

#### 2.2.1.2 Cabinet Interiors Sound Attenuation

Provide a factory-installed sound attenuation system in the interior of the CRAC unit cabinet.

CRAC unit cabinet panels interior shall be provided with one inch of 1 1/2 pound per cubic foot neoprene-coated fiber glass insulation on interior of cabinet panels. Insulation shall be applied to the cabinet panels with 100 percent adhesive coverage and both the insulation and the adhesive shall conform to NFPA 90A.

Fans located in the CRAC unit interior cabinet shall be provided with vibration isolators between their respective support frames and the cabinet framing.

CRAC unit manufacturer's standard interior cabinet sound attenuation materials and finishes will be acceptable if considered equivalent to the above requirements by the Contracting Officer.

#### 2.2.2 Fan Section

Fans which force air through coils into computer rooms shall have direct drives, sized to ensure achievement of design air flow by field adjustments.

The fan motor shall be drip-proof with NEMA rated frame, inherent overload protection, and sliding adjustable motor base. The maximum vibrations shall not exceed 2 mils in any plane.

Floor mounted upflow CRAC unit supply air fans shall be plenum type fans, integral direct drive, with backward-curved blades and electronically commutated (EC) DC motor. Fan speed shall be variable and automatically regulated by unit controls through all modes of operation. Each fan shall have a dedicated motor, fault monitoring circuitry and speed controller.

### 2.2.3 Cooling Coil

Provide AHRI 410 coils and slope for drainage. Coil shall be constructed of seamless copper tubes with plate aluminum fins. Indoor and outdoor coils shall be matched and from same manufacturer. Use a low sensible heat ratio for more moisture removal. Each coil, in the production process, shall be individually tested at 320 psi with compressed air under water and verified to be air tight. Provide hydronic coils complete with drain and vent connections. Provide condensate drain pan of stainless steel construction with nonferrous connections and internal trap. Provide a packaged condensate pump system complete with integral pump discharge check valve, integral float switch, reservoir, and pump and motor assembly.

### 2.2.4 Filters

Provide UL listed 4 inches thick deep pleated fiberglass throwaway type filters for all horizontally mounted CRAC units. Provide filtration media with a Minimum Efficiency Reporting Value (MERV) of 8 as determined by ASHRAE 52.2. Provide one complete spare filter bank set for installation prior to final acceptance testing covered in Part 3 of this section. Provide UL listed 2 inch thick deep pleated fiberglass throwaway type filters with a MERV 8 rating for all floor mounted upflow units.

### 2.2.5 Electric Reheat Coil

Electric reheat coils shall be factory installed, wired and controlled low-watts density, 304/316 stainless steel, finned-tubular and shall be designed to maintain design room dry bulb temperature conditions when cooling coil is in a dehumidification operational mode. The electric reheat coil assembly shall include a UL-approved safety switch to protect system from overheating. A ground current detector shall be factory installed to shut-down the entire unit if a ground fault in the electric reheat system is detected. Provide staged control of electric reheat as scheduled on the drawings.

### 2.2.6 Humidifier

Humidifier section shall include liquid-level control, emergency overflow and automatic water supply system factory pre-piped for final connection. Provide stainless steel evaporator pan with water high level and low level alarms. Arrange system to be cleanable and serviceable.

Provide infrared type humidifier consisting of high-intensity quartz lamps mounted above and out of the water supply. Humidifier drain pan shall be serviceable without disconnecting water supply lines, drain lines or electrical connections. The infrared humidification system shall use by-pass air to prevent over-humidification of the controlled space. A packaged auto-flush system shall automatically flush deposits from the humidifier pan. System shall be field adjustable.

### 2.2.7 Space Temperature Control System

Provide microprocessor control system integral with each unit including electronic control center, control valves, sensors, wiring, and other appurtenances for workable system. Provide access panel or door in front of unit.

Isolate electronic control center from conditioned airstream to allow service while system is in operation. Provide control sensors in unit for



cooling, dehumidifying, and humidifying. High-voltage circuits in system shall have individual leg overload protection. Starters, contactors, and relays shall be controlled by 24 volt control circuit.

High-voltage circuit components shall be protected by safety lock, dead-front panel. Mount nonautomatic, molded-case circuit breaker in high-voltage section of electrical panel. Operating mechanism shall prevent access to high-voltage electrical components until switched to "OFF" position.

Include the following control capabilities:

- a. Capable of changing the set points and sensitivity of the space and humidity along with their low and high alarm points.
- b. Logging capability of the last 10 alarms and run time.
- c. Diagnostics

Provide a controls interface on each CRAC unit to enable the DDC system to monitor the following operating parameters and alarm conditions: high and low computer room temperature, relative humidity, CRAC status, dirty filters, loss of airflow and humidifier problems.

#### 2.2.8 Air Return and Delivery Orientation

Computer room air conditioning units shall be floor mounted, upflow, rear returns indicated on the drawings and shall be provided with duct connection collars. Provide acoustical lining on the interior in compliance with requirements specified hereinbefore in paragraph CABINET INTERIORS SOUND ATTENUATION.

#### 2.3 COMPUTER ROOM AIR CONDITIONING UNITS (CRAC) (HORIZONTAL SUSPENDED FROM STRUCTURE)

ANSI/ASHRAE 15 & 34. Provide self-contained units, designed, factory assembled, and factory tested. Unit shall be listed in UL Elec Equip Dir or ETL DLP for computer room application. Unit shall include cabinet and frame, fan section, filter section, chilled water cooling coil, hot water reheat coil, canister type steam generator humidifier, controls, and, interconnecting piping internal to the CRAC unit. CRAC units shall be designed for horizontal installation suspended from structures as scheduled and indicated on drawings.

##### 2.3.1 Cabinet and Frame

###### 2.3.1.1 Unit Cabinet

Unit frame shall be minimum 14 gage welded steel tubes or steel angles and shall be mill-galvanized or coated with an epoxy finish, or an approved manufacturer's standard finish, if equivalent.

Exterior panels shall be furniture grade steel sheet, minimum of 20 gage, mill-galvanized or coated with a corrosion-inhibiting epoxy finish, or an approved equivalent finish. Mill galvanized sheet metal shall be coated with not less than 1.25 ounces of zinc per square foot of two-sided surface. Mill rolled structural steel shall be hot-dip galvanized or primed and painted. Cut edges, burns and scratches in hot-dip galvanized surfaces shall be coated with galvanizing repair coating.

Provide removable panel for access from one side to controls without interrupting airflow. Panels shall be gasketed to prevent air leakage under system operating pressure and shall be removable for service access without the use of special tools. Condensate pans shall be minimum 22 gage Type 304 stainless steel, non-corroding, double-sloped, and shall be piped to drain.

Exterior surfaces of cabinets constructed of mill-galvanized steel shall be finished by the manufacturer's standard enamel finish in the specified color.

CRAC unit manufacturer's standard cabinet materials and finishes will be acceptable if considered equivalent to the above requirements by the Contracting Officer.

#### 2.3.1.2 Cabinet Interiors Sound Attenuation

Provide a factory-installed sound attenuation system in the interior of the CRAC unit cabinet.

CRAC unit cabinet panels interior shall be provided with one inch of 1 1/2 pound per cubic foot neoprene-coated fiber glass insulation on interior of cabinet panels. Insulation shall be applied to the cabinet panels with 100 percent adhesive coverage and both the insulation and the adhesive shall conform to NFPA 90A.

Fans located in the CRAC unit interior cabinet shall be provided with vibration isolators between their respective support frames and the cabinet framing.

CRAC unit manufacturer's standard interior cabinet sound attenuation materials and finishes will be acceptable if considered equivalent to the above requirements by the Contracting Officer.

#### 2.3.2 Fan Section

Fans which force air through coils into computer rooms shall be direct drive, sized to ensure achievement of design air flow by field adjustments. Fan system design shall be 2-speed or EC motor drive.

Horizontal installation suspended from the structure unit supply air fan shall be AMCA certified, double-inlet/double-width, and equipped with forward-curved blades wheel. The supply air fan shall be statically and dynamically balanced. The fan shall have self-aligning, permanently lubricated ball bearings with a minimum life span of 100,000 hours. Assess potential effects of lubricant on aquatic organisms in accordance with ASTM D6081 and submit aquatic toxicity reports. Assess biodegradation in accordance with ASTM D5864. In accordance with EM 1110-2-1424 Chapter 8, aquatic toxicity shall exceed 1,000 ppm at LL50 and biodegradation shall exceed 60 percent conversion of carbon to carbon dioxide in 28 days.

The fan motor shall be drip-proof with NEMA rated frame, inherent overload protection, and sliding adjustable motor base. The maximum vibrations shall not exceed 2 mils in any plane.

### 2.3.3 Cooling Coil

Provide AHRI 410 coils and slope for drainage. Coil shall be constructed of seamless copper tubes with plate aluminum fins. Use a low sensible heat ratio for more moisture removal. Each coil, in the production process, shall be individually tested at 320 psi with compressed air under water and verified to be air tight. Provide hydronic coils complete with drain and vent connections. Provide condensate drain pan of stainless steel construction with nonferrous connections and internal trap. Provide a packaged condensate pump system complete with integral pump discharge check valve, integral float switch, reservoir, and pump and motor assembly.

### 2.3.4 Filters

Provide UL listed 4 inches thick deep pleated fiberglass throwaway type filters for all horizontally mounted CRAC units. Provide filtration media with a Minimum Efficiency Reporting Value (MERV) of 8 as determined by ASHRAE 52.2. Provide one complete spare filter bank set for installation prior to final acceptance testing covered in Part 3 of this section.

### 2.3.5 Heating Water Reheat Coil

Provide AHRI 410 reheat coils and slope for drainage. Provide coil constructed of seamless copper tubes with plate aluminum fins. Each coil, in the production process, shall be individually tested at 320 psi with compressed air under water and verified to be air tight.

### 2.3.6 Humidifier

Humidifier section shall include liquid-level control, emergency overflow and automatic water supply system factory pre-piped for final connection. Provide stainless steel evaporator pan with water high level and low level alarms. Arrange system to be cleanable and serviceable.

Provide steam generator type humidifiers that are controlled by the unit microprocessor control system. Humidifier system shall be complete with disposable canister, all supply and drain valves, inlet strainer, steam distributor and electronic controls. CRAC unit controls shall provide a "change canister" signal to the facility DDC System. An LED light on the humidifier assembly shall indicate cylinder full, overcurrent detection, fill system fault and end of cylinder life conditions. Canister flush water shall not drain into the cooling coil drain pan.

### 2.3.7 Space Temperature Control System

Provide microprocessor control system integral with unit including electronic control center, control valves, sensors, wiring, and other appurtenances for workable system. Provide access panel or door in front of unit.

Isolate electronic control center from conditioned airstream to allow service while system is in operation. Provide control sensors in unit for cooling, dehumidifying, and humidifying. High-voltage circuits in system shall have individual leg overload protection. Starters, contactors, and relays shall be controlled by 24 volt control circuit.

High-voltage circuit components shall be protected by safety lock, dead-front panel. Mount nonautomatic, molded-case circuit breaker in high-voltage section of electrical panel. Operating mechanism shall

prevent access to high-voltage electrical components until switched to "OFF" position.

Include the following control capabilities:

- a. Capable of changing the set points and sensitivity of the space and humidity along with their low and high alarm points.
- b. Logging capability of the last 10 alarms and run time.
- c. Diagnostics

Provide a DDC System controls interface on CRAC unit to enable the DDC System system to monitor the following operating parameters and alarm conditions: high and low computer room temperature, relative humidity, CRAC unit status, humidifier status, humidifier alarms.

#### 2.3.8 Alarm Panel System

Provide unit with cabinet-mounted alarm panel which shall monitor high and low space temperature, high and low space humidity, dirty filters, and loss of airflow, loss of water flow, compressor high head pressure. Provide field accessible local audible alarm with silence pushbutton. Provide push-to-test lamps or all-lamp test pushbutton. CRAC units shall have local devices which provide signals for remote audible and visual alarming capability for the above specified alarm conditions.

### 2.4 ELECTRICAL

#### 2.4.1 Electrical Motors, Controllers, Contactors, and Disconnects

Furnish with respective pieces of equipment. Motors, controllers, contactors, and disconnects shall conform to Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM, as modified and supplemented by this section. Provide electrical connections under Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide controllers and contactors with maximum of 120-volt control circuits, and auxiliary contacts for use with controls furnished. Motors shall be designed for variable-speed service. 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.

#### 2.4.2 Electrical Control Wiring

Provide control wiring under Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC. Provide control wiring under this section in accordance with NFPA 70 and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide Space temperature control system drawings which include point-to-point electrical wiring diagrams.

### 2.5 HVAC WATER PIPING AND METAL DUCTWORK

Requirements for HVAC water piping and metal ductwork are specified in Section 23 64 26 CHILLED WATER PIPING AND ACCESSORIES, Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEMS and Section 23 52 00 HEATING BOILERS..

### PART 3 EXECUTION

#### 3.1 CONSTRUCTION-RELATED SUSTAINABILITY CRITERIA

Perform and document the following:

##### 3.1.1 Indoor Air Quality During Construction

Provide documentation showing that after construction ends, and prior to occupancy, new filters were installed in conformance with Section 01 33 29 SUSTAINABILITY REPORTING paragraph INDOOR AIR QUALITY DURING CONSTRUCTION.

#### 3.2 INSTALLATION

##### 3.2.1 CRAC Unit System

Installation of each CRAC unit system including equipment, materials, installation, workmanship, fabrication, assembly, erection, examination, inspection, and testing, shall be in accordance with ASME B31.1, ASME B31.5, NFPA 70, as modified and supplemented by the requirements of this section and the CRAC unit manufacturer's recommendations.

##### 3.2.2 Installation Instructions

Provide a manufacturer's installation manual for each type of CRAC unit.

#### 3.3 FIELD QUALITY CONTROL

Upon completion and before final acceptance of work, test each CRAC unit subsystem in service to demonstrate compliance with the contract requirements, including field testing specified below. Adjust controls and balance systems prior to final acceptance of completed systems. Test controls through every cycle of operation. Test safety controls to demonstrate performance of required function. Correct defects in work provided by Contractor and repeat tests. Furnish water, electricity, instruments, connecting devices, and personnel for tests. Flush and clean piping before placing in operation. Clean equipment, piping, strainers, and ducts. Prior to commencement of field testing, remove all filters and provide new filters.

#### 3.4 FIELD TESTING

Provide field test plans, field test schedules, field tests and field test reports on each of the CRAC units. Field test each CRAC unit for Contracting Officer acceptance in accordance with the CRAC unit manufacturer's approved field test plan.

##### 3.4.1 Manufacturer's Field Test Plans

Submit field test plans developed by the manufacturer for each CRAC unit; submit the field test plans at least 90 calendar days prior to planned date of the field test. Field test plans developed by the installing Contractor, or the equipment sales agency furnishing the CRAC unit, will not be acceptable.

The Contracting Officer will review and approve the field test plan for each of the listed CRAC units prior to commencement of field testing of the equipment. The approved field test plans shall be followed for the field tests of the CRAC unit and test reporting.

#### 3.4.1.1 Coordinated Testing

Indicate in each field test plan when work required by this section requires coordination with test work required by other specification sections. Furnish test procedures for the simultaneous or integrated testing of: CRAC unit controls which interlock and interface with controls factory prewired.

#### 3.4.1.2 Prerequisite Testing

Each CRAC unit for which performance testing is dependent upon the completion of the work covered by Section 23 05 93 TESTING, ADJUSTING AND BALANCING FOR HVAC must have that work completed as a prerequisite to testing work under this section. Indicate in each field test plan when such prerequisite work is required.

#### 3.4.1.3 Test Procedure

Indicate in each field test plan the CRAC unit manufacturer's published start-up, and field acceptance test procedures. Include in each test plan a detailed step-by-step procedure for testing automatic controls provided by the manufacturer.

Procedures shall be structured to test the controls through all modes of control to confirm that the controls are performing with the intended sequence of control.

Controllers shall be verified to be properly calibrated and have the proper set point to provide stable control of their respective equipment.

#### 3.4.1.4 Performance Variables

Each test plan shall list performance variables that are required to be measured or tested as part of the field test.

Include, in the listed performance variables, requirements indicated on the CRAC unit schedules on the design drawings. Manufacturer shall furnish, with each test procedure, a description of acceptable results that have been verified.

Manufacturer shall identify the acceptable limits or tolerances within which each tested performance variable shall acceptably operate.

#### 3.4.1.5 Test Configuration

Plans shall indicate that tests are to be performed for a minimum of four continuous hours in a wet coil condition. If test period is interrupted, the four hour test period shall be started over. Each test plan shall be job specific and shall address the particular CRAC units and particular conditions which exist with this contract. Generic or general preprinted test procedures are not acceptable. Tests shall include with or without the air discharge elbows; or a top air discharge configuration.

#### 3.4.1.6 Tested Variables

Plans shall provide for air side testing which includes verification of the airflow, total static pressure; fan drive motor KW, amperage and RPM; and fan RPM. Provide entering air temperatures equal to those indicated on

the CRAC unit schedules.

#### 3.4.1.7 Thermal Testing

Plans shall provide thermal testing utilizing chilled water and hot water with temperatures equal to those indicated on the CRAC unit schedules. Thermal testing shall verify CRAC unit heating, sensible cooling, total cooling, and humidifying performance scheduled on the contract drawings.

#### 3.4.1.8 Specialized Components

Include procedures for field testing and field adjusting specialized components, such as hot gas bypass control valves, or pressure valves.

#### 3.4.1.9 Field Test Reporting Forms

Each test plan shall include the required test reporting forms to be completed by the Contractor's testing representatives.

#### 3.4.2 Field Test Schedule

Notify the Contracting Officer in writing at least 30 calendar days prior to the testing. Within 30 calendar days after acceptable completion of testing, submit each test report for the review and approval of the Contracting Officer.

#### 3.4.3 Manufacturer's Test Representative

Furnish a factory trained field test representative authorized by the CRAC unit manufacturer to oversee the complete execution of the field testing. This test representative shall also review, approve, and sign the completed field test report. Signatures shall be accompanied by the person's name typed.

Submit credentials of the manufacturer's field test representative proposed, including current telephone number, to the Contracting Officer for review and approval. Submit these credentials with the written advance notice of the field tests

#### 3.4.4 Field Tests

Conduct the field testing in compliance with the Contracting Officer approved manufacturer's field test plan, and in accordance with additional field testing requirements specified herein. Record the required data using the test reporting forms approved of the approved field test plan. Conduct the test for each CRAC unit for a continuous 24-hour test period. A CRAC unit shutdown before the continuous 24-hour test period is completed shall result in the 24-hour test period being started again and run for the required duration.

#### 3.4.5 Deficiency Resolution

The test requirements shall be acceptably met; deficiencies identified during the tests shall be corrected in compliance with the manufacturer's recommendations. Corrections shall be tested again in compliance with the requirements specified in the paragraph FIELD TEST PLANS.

#### 3.4.6 Field Test Reports

Use the test reporting forms approved in the field test plan. Final test report forms shall be typed, including data entries and remarks. Completed test report forms for each CRAC unit shall be reviewed, approved, and signed by the Contractor's test director and the QC manager.

-- 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" or "S" classification. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. 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

User Interface Requirements for LOW Impact HVAC Control Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u>
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:

- 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.

- 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.
- 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" or "S" classification. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. 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

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
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) 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 11.03

CYBERSECURITY FOR MODERATE IMPACT ELECTRONIC SECURITY SYSTEMS (ESS)  
**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 ELECTRONIC SECURITY SYSTEMS (ESS).

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.

#### 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. Writable User Interfaces in Electronic Security Systems (ESS) are privileged user interfaces.
- 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" or "S" classification. Submittals not having a "G" or "S" classification are for information only. 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

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

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

Integrity Verification Software; G

## 1.7 QUALITY CONTROL

### 1.7.1 Subject Matter Expert Qualifications

For the Electronic Security Systems (ESS) 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...

#### 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 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.

### 3.2.2.1 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.

### 3.2.2.2 Non-IP Wireless Communication

For MODERATE Impact Systems: When non-IP wireless communication is explicitly authorized by the Government, the radios must meet NIST FIPS 140-2 Level 2.

### 3.2.2.3 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.

### 3.2.2.4 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.

### 3.2.3 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 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 Electronic Security Systems (ESS)

User Interface Requirements for MODERATE Impact Electronic Security Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u> (See note 3)
Local Read Only (see note 1)	KEY
Local Limited, Non-privileged	NA

User Interface Requirements for MODERATE Impact Electronic Security Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u> (See note 3)
Local Limited, Privileged	FULLY
Local Full	FULLY and Physical Security
Remote Read Only	MINIMALLY
Remote Limited, Non-Privileged	NA
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)Devices outside mission space require physical security protections as indicated  
 (in "PHYSICAL SECURITY IN MODERATE IMPACT SYSTEMS")

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 MODERATE Impact Control Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u> (See note 3)
Local Read Only (see note 1)	None Required
Local Limited, Non-privileged	None Required
Local Limited, Privileged	MINIMALLY and Physical Security
Local Full	MINIMALLY and Physical Security
Remote Read Only	None Required
Remote Limited, Non-Privileged	FULLY
Remote Limited, Privileged AND Remote Full (see note 2)	FULLY

Default User Interface Requirements for MODERATE Impact Control Systems	
<u>User Interface Type</u>	<u>Access Control Requirement</u> (See note 3)
Notes: 1)Local Read Only User Interfaces are always Non-Privileged 2)Remote Full User Interfaces are always Privileged 3)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 account after 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.

#### 3.3.4.3 Session Lock and Termination for Computers

User Interface sessions provided by computer operating systems must support the requirement for both Session Lock and Session Termination. Session Lock and Session Termination must be capable of being initiated by the user and must also be initiated by lack of activity. Session Lock must occur after 15 minutes of inactivity, and Session Termination must occur after 30 minutes total of inactivity (including, not in addition to, the time for Session Lock). When a user initiates a new session, terminate existing sessions if necessary to limit the total number of concurrent sessions to 1.

Other User Interface sessions running on computers (for local user interfaces) or hosted on a computer (for remote user interfaces) and supporting accounts must support user initiation of Session Termination and session lock. Session lock may be initiated by user initiation or automatically after 15 minutes of inactivity. In addition, remote User Interface sessions must also initiate Session Termination after 30 minutes of inactivity .

#### 3.3.4.4 Session Lock and Termination for Controllers

Writable Remote User Interfaces must support requirements for Session Termination, and must both be capable of being initiated by the user and initiated by lack of activity. Session Termination must initiate after 30 minutes of inactivity.

Local User Interfaces supporting accounts must support manual initiation of Session Termination. Privileged Local User Interfaces must also support timed initiation of Session Termination, with Session Termination initiated at 30 minutes of inactivity. They must also support session lock, where session lock may be initiated by user initiation or automatically after 15 minutes of inactivity.

### 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.

#### 3.3.6.2 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).

#### 3.3.6.3 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. Devices with writable 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.

##### 3.4.2.1 Electronic Security System Devices

User interfaces which FULLY support accounts and which run on a computer must use multifactor authentication via PIV. User interfaces which MINIMALLY support accounts must use either passwords or multifactor authentication via PIV.

#### 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.

### 3.8 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 copy 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/>): electronic security systems(ESS).

### 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 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" or "S" classification. Submittals not having a "G" or "S" classification are for

information only. 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 10 10

UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION  
02/19

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: ASHRAE 135 (BACnet) 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 an IP network as specified in 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS and 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.

#### 1.1.2 General Cybersecurity Requirements

Address cybersecurity in accordance with AF ETL 11-1.

#### 1.1.3 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.

#### 1.1.4 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.

#### 1.1.5 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 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 (2017) Fundamentals Handbook, I-P Edition

### CONSUMER ELECTRONICS ASSOCIATION (CEA)

CEA-709.1-D (2014) Control Network Protocol Specification

CEA-852-C (2014) Tunneling Device Area Network Protocols Over Internet Protocol Channels

### INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 802.11 (2016; AI 2017; AJ 2018; AK 2018; AQ 2018) 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

IEEE 1815 (2015; CORR 2016) Exchanging Information Between Networks Implementing IEC 61850 and IEEE Std 1815

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



INTERNET ENGINEERING TASK FORCE (IETF)

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 (2019) 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-C.1 (2009; Add 2 2011; Add 1 2012) Commercial  
Building Telecommunications Cabling  
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 (2012) NiagaraAX User's Guide

U.S. AIR FORCE (USAF)

AF ETL 11-1 (2011) Civil Engineer Industrial Control  
System Information Assurance Compliance

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 Sep 2017) UL Standard for  
Safety Uninterruptible Power Systems

UL 60950 (2000; Reprint Oct 2007) Safety of  
Information Technology Equipment

1.3 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.

1.3.1 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.

1.3.2 Alarm Handling

see Alarm Routing

1.3.3 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.

1.3.4 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.

1.3.5 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.

#### 1.3.6 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.

#### 1.3.7 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.

#### 1.3.8 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.

#### 1.3.9 BACnet Internetwork (BACnet)

Two or more BACnet networks connected with BACnet routers. In a BACnet Internetwork, there exists only one message path between devices.

#### 1.3.10 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.

#### 1.3.11 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.

1.3.12 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.

1.3.13 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.

1.3.14 BACnet Smart Sensor (B-SS)(BACnet)

A hardware device BTL Listed as a B-SS. A simple sensing device with very limited resources.

1.3.15 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.

1.3.16 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".

1.3.17 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'.

1.3.18 Broadcast

Unlike most messages, which are intended for a specific recipient device, a broadcast message is intended for all devices on the network.

1.3.19 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.

1.3.20 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.

1.3.21 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)

#### 1.3.22 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.

#### 1.3.23 Control Logic Diagram

A graphical representation of control logic for multiple processes that make up a system.

#### 1.3.24 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.

#### 1.3.25 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.)

#### 1.3.26 Field Control Network

The network used by a field control system.

#### 1.3.27 Field Control System (FCS)

A building control system or utility control system.

#### 1.3.28 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.

#### 1.3.29 Internetwork (BACnet)

See BACnet Internetwork.

#### 1.3.30 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.

#### 1.3.31 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.

#### 1.3.32 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.

#### 1.3.33 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.

#### 1.3.34 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.

#### 1.3.35 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.

#### 1.3.36 Point, Network

A value that the M&C Software reads from or writes to a field control network.

#### 1.3.37 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.

#### 1.3.38 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.

#### 1.3.39 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.

#### 1.3.40 Repeater

A device that connects two control network segments and retransmits all information received on one side onto the other.

#### 1.3.41 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.

#### 1.3.42 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.

#### 1.3.43 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).

#### 1.3.44 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.

#### 1.3.45 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.

#### 1.3.46 Supervisory Gateway

A device that is both a supervisory controller and a gateway.

#### 1.3.47 UMCS Network

An IP network connecting multiple field control systems to the Monitoring and Control Software using one or more of: BACnet (ASHRAE 135 Annex J).

#### 1.3.48 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.

#### 1.4 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. 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 and TABLE 1: PROJECT SEQUENCING:

##### SD-02 Shop Drawings

###### UMCS Contractor Design Drawings; G

UMCS Contractor Design Drawings as a single complete package: hard copies and copies on CDROM. Submit hardcopy drawings on sheets, and electronic drawings in both PDF and AutoCAD format.

###### Draft As-Built Drawings; G

Draft As-Built Drawings as a single complete package: hard copies and copies on CDROM. Submit hardcopy drawings must on sheets, and electronic drawings in both PDF and AutoCAD format.

###### Final As-Built Drawings; G

Final As-Built Drawings as a single complete package: hard copies and copies on CDROM. Submit hardcopy drawings on 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

##### 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.

Factory Test Procedures

SD-10 Operation and Maintenance Data

Operation and Maintenance (O&M) Instructions; G

Four bound O&M Instructions and 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.

1.5 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).

1.5.1 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.

1.5.2 Sequencing for Activities

The sequencing specified for activities indicates the earliest the activity may begin.

1.5.3 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	After #1
3	S	Design Drawings	After #1
4	S	Product Data Sheets	After #1
5	S	UMCS IP Network Bandwidth Usage Estimate	After #1
6	S	Pre-construction QC Checklist	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	ACO #8
10	S	Computer Software	ACO #8
11	S	Start-Up and Start-Up Testing Report	ACO #8
12	S	Draft As-Built Drawings	ACO #8
13	S	PVT Phase I Procedures	Before scheduled start of #14 and AAO #11
14	E	PVT Phase I	AAO #13 and #12
15	S	PVT Phase I Report	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 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	ACO #19
21	S	Final As-Built Drawings	AAO #20
22	S	Advanced Training Documentation	Before schedule start of #23 and AAO #18
23	E	Advanced Training	ACO #19, AAO #22, and ACO #19
24	S	Refresher Training Documentation	Before #25 and AAO #18 and #22
25	E	Refresher Training	ACO #19 and AAO #24
26	S	Closeout QC Checklist	ACO #23

1.6 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.

1.7 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 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, or other ASHRAE 135 network. Devices used as BACnet/IP Routers must be BTL Listed and must support the Network Management-Router Configuration-B (NM-RC-B) BIBB.

### 2.2.2 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.

#### 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) must be a desktop or server computer meeting the following minimum requirements:

#### 2.3.1.1 Processor

Quad-core processor designed for server applications. Processor speed must be at least 50 percent of the speed of the fastest Intel server processor commercially available.

#### 2.3.1.2 Random Access Memory (RAM)

300 percent of the recommended requirements of the software to be installed on the server and no less than 24GB.

#### 2.3.1.3 Communications Ports

Four USB ports.

#### 2.3.1.4 Hard Drives

##### 2.3.1.4.1 Internal Hard Drives

Hard drives with SATA-3 Controller providing at least 2TB usable disk space. Hard drives must use RAID (Redundant Array of Inexpensive Disks) at levels 1 or 5 (RAID-1 or RAID-5).

##### 2.3.1.4.2 External Hard Drive

4TB disk space with a USB 3.0 interface.

#### 2.3.1.5 Optical Drive

Blueray burner drive.

#### 2.3.1.6 Video Output

32-bit color at a minimum resolution of 1920 by 1080 at a minimum refresh rate of 70 Hz and a DVI or display port output.

#### 2.3.1.7 Network Interface

Two integrated 1000Base-T Ethernet with RJ45 connector.

#### 2.3.1.8 Monitor

Widescreen flat panel LCD monitor sized as indicated but no less than 24 inch nominal with a minimum resolution of 1600 by 1050 pixels and a minimum refresh rate of 70Hz.

#### 2.3.1.9 Keyboard

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).

#### 2.3.1.10 Mouse

2-button wired USB optical scroll mouse with a minimum resolution of 400

dots per inch.

#### 2.3.1.11 Power Supplies

Hot-swappable redundant power supplies.

### 2.3.2 Workstation Hardware (Desktop and Laptop)

Provide a standard desktop computer or a laptop meeting the following minimum requirements for the Computer Workstation Hardware (workstation) as indicated.

#### 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

#### 2.4 COMPUTER SOFTWARE

##### 2.4.1 Operating System (OS)

Provide the latest version of the Gold Master Windows Operating System. The Operating System media will be furnished by the Government. Provide the Operating System license.

##### 2.4.2 Office Automation Software

Provide Office Automation Software consisting of the e-mail, spreadsheet and word processing portions of the project site's standard office automation software.

##### 2.4.3 Virus Protection Software

Provide Virus Protection Software consisting of the project site's standard virus protection software complete with a virus definition update subscription.

#### 2.4.4 Disk Imaging (Backup) Software

Provide Disk imaging (backup) software capable of performing a bare-metal restore (imaging and restoring to a new blank hard drive such that restoration of the image is sufficient to restore system operation to the imaged state without the need for re-installation of software). Provide Disk imaging (backup) software consisting of the project site's standard disk imaging software.

#### 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 via ASHRAE 135, and 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 3000 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 the handling (routing) of alarms for no less than 10,000 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.

#### 2.4.7.2 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.
- 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.
- 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 footprint 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

- 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 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 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, 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 .

- 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 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 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

#### 2.4.7.17.9 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 4 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 FACTORY TEST

Perform factory testing of the UMCS as specified. The Contractor is responsible for providing personnel, equipment, instrumentation, and supplies necessary to perform required testing. Provide written notification of planned testing to the Government at least 21 days prior to testing, and do not give this notice until after receiving written Government approval of the specific Factory Test Procedures. Provide Factory Test Procedures which define the tests required to ensure that the system meets technical, operational, and performance specifications. Within the Procedures define location of tests, milestones for the tests, and identify simulation programs, equipment, personnel, facilities, and supplies required. Provide procedures which test all capabilities and functions specified and indicated. Develop Procedures from the design documentation. Perform the Factory Test using equipment and software of the same manufacturer, model and revision as will be used for the specified project. Include detailed instructions for test setup, execution, and evaluation of test results in the Procedures. Upon completion of the test, prepare a documenting the results of the Test, and submit it as specified.

Perform the Factory Test and provide Factory Test Submittals as shown in TABLE II. FACTORY TEST SEQUENCING.

TABLE II. FACTORY TEST SEQUENCING

ITEM #	DESCRIPTION	SEQUENCING
		(START OF ACTIVITY or DEADLINE FOR SUBMITTAL)
1	Submit Factory Test Procedures	After notice to proceed
2	Perform Factory Test	After Approval Of #1

### 3.2 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.

### 3.3 DRAWINGS AND CALCULATIONS

#### 3.3.1 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.

#### 3.3.2 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.

#### 3.3.3 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.

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.

### 3.4 INSTALLATION REQUIREMENTS

#### 3.4.1 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.

#### 3.4.2 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.

#### 3.4.3 Nameplates

Provide Nameplates for all Control Hardware and all Computer Hardware. Attach Nameplates to the device in a conspicuous location.

### 3.5 INSTALLATION OF EQUIPMENT

#### 3.5.1 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-C.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.

#### 3.5.2 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.

### 3.5.3 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.

### 3.5.4 IP Addresses

For all Control Hardware requiring an IP address on the UMCS IP Network, coordinate with the Government to obtain IP addresses.

### 3.5.5 Computer Hardware and Software

#### 3.5.5.1 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.

#### 3.5.5.2 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 Government for user names and passwords.

h. Office Automation Software: Install the office automation software on each server and workstation.

i. Virus Protection software: Install the virus protection software on

each server and workstation and configure weekly virus scans.

- j. Disk Imaging (Backup) Software: Install the disk imaging (backup) software on each server and configure for imaging the internal hard drive to external hard drive.

Where software requires connection to an IP device outside of the UMCS, coordinate with Government 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 Government.

#### 3.5.5.3 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 and passwords. Coordinate user accounts, passwords 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 Government.

#### 3.5.5.4 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.

#### 3.6 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.

### 3.6.1 Integration Step 1: Install Control Hardware

Install Control Hardware as specified at the FPOC location as shown 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 Government. 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.

#### 3.6.1.1 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. 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 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.

#### 3.6.1.2 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 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.

### 3.6.1.3 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.

### 3.6.2 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.

#### 3.6.2.1 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.

#### 3.6.2.2 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.

#### 3.6.2.3 Integration of Field Control Systems Via Other Integration of Field Control Systems Via Other (non-ASHRAE 135, non-OPC DA) Protocols

Perform all actions necessary to make all points as shown on the Points Schedule from the field control system available in the M&C Software.

### 3.6.3 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.

#### 3.6.3.1 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.

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

### 3.6.3.2 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 including overrides, as shown on the Points Schedule and as specified. Label all points on displays with the point name as shown on the Points Schedule. Configure user permissions for access to and executions of action using graphic pages. Coordinate user permissions with the Controls shop supervisor.
- b. Configure 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. Create and configure Schedule Objects in BACnet Supervisory Controllers or in the field control system.

Create and configure displays for configuration of 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 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 15minute 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.

### 3.7 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.

### 3.8 PERFORMANCE VERIFICATION TEST (PVT)

#### 3.8.1 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.

#### 3.8.2 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.

#### 3.8.3 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.

### 3.9 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.

#### 3.9.1 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.

### 3.9.2 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.

### 3.9.3 Working Hours

Working hours are from 7:30 A.M. to 4:00 P.M. local time Mondays through Fridays except Federal holidays.

### 3.9.4 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.

### 3.9.5 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.

### 3.9.6 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.

#### 3.9.7 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.

#### 3.9.8 Preventive Maintenance Requirements

Prepare a Preventive Maintenance Work Plan as specified.

##### 3.9.8.1 Preventive Maintenance Work Plan

Prepare a Preventive Maintenance Work Plan detailing 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.

#### 3.9.9 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 24 hours per day, seven days a week, including weekends and holidays. 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.

#### 3.9.10 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.

#### 3.9.11 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.

#### 3.10 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.

##### 3.10.1 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:

###### 3.10.1.1 Course Attendance List

Course Attendance List developed in coordination with and signed by the Controls shop supervisor.

### 3.10.1.2 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.

### 3.10.2 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.

### 3.10.3 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.

#### 3.10.4 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.		
<b>Verify the following items for Pre-Construction, Post-Construction and Closeout QC Checklist Submittals:</b>		
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 . M&C Software is BTL Listed as a B-AWS.	___
<b>Verify the following items for Post-Construction and Closeout QC Checklist Submittal:</b>		
3	Communication between the M&C Software and ASHRAE 135 field control systems uses only ASHRAE 135.	___
4	Connections to non-ASHRAE 135field control systems are via a Gateway from the field control system to ASHRAE 135 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.	___
<b>Verify the following items for Closeout QC Checklists Submittal:</b>		
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.	___

<u>QC CHECKLIST</u>		
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.	___
14	Basic Operator and Advanced Training courses have been completed.	___
_____		
	(QC Representative Signature)	(Date)

-- 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" 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 Notebook, in conformance to Section 01 33 29 SUBMITTAL REPORTING. 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.

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  $8 \text{ cal/cm}^2$  provide recommendations to reduce the arc flash energy to  $4 \text{ cal/cm}^2$ .

### 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 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.

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 C2	(2023) National Electrical Safety Code
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
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NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION (NECA)

NECA NEIS 1	(2015) Standard for Good Workmanship in Electrical Construction
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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)
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 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
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-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 5 (2016; Reprint Jul 2022) UL Standard for Safety Surface Metal Raceways and Fittings
- UL 6 (2022) UL Standard for Safety Electrical Rigid Metal Conduit-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 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 797	(2007; Reprint Apr 2023) UL Standard for Safety Electrical Metallic Tubing -- Steel
UL 869A	(2006; Reprint Jun 2020) Reference Standard for Service Equipment
UL 870	(2016; Reprint Nov 2023) UL Standard for Safety Wireways, Auxiliary Gutters, and Associated Fittings
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 1004-1	(2012; Reprint Nov 2020) UL Standard for Safety Rotating Electrical Machines - General Requirements
UL 1063	(2017; Reprint Jun 2022) UL Standard for Safety Machine-Tool Wires and Cables
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 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

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 Notebook, in conformance with 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

Wireways; G

SD-03 Product Data

Receptacles; G  
Circuit Breakers; G  
Switches; G  
Transformers; G  
Enclosed Circuit Breakers; G  
Motor Controllers; G  
Manual Motor Starters; G  
Surge Protective Devices; G  
Cable Trays  
Secondary Bonding Busbar

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

SD-11 Closeout Submittals

Marking Strips

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.

2.2.2 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 SURFACE RACEWAY

2.3.1 Surface Metal Raceway

UL 5, two-piece painted steel, totally enclosed, snap-cover type.

## 2.4 CABLE TRAYS

### 2.4.1 Basket-Type Cable Trays

Provide size as indicated width and depth with maximum wire mesh spacing of 2 by 4 inch.

### 2.4.2 Ladder-Type Cable Trays

Provide size as indicated width with maximum rung spacing of 9 inches. Cable tray must be suitable for use as an equipment grounding conductor.

## 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 ring, and cover plate with 1 inch threaded plug.
- c. Telecommunications outlets: consisting of flush, aluminum or stainless steel housing with a receptacle as specified and one inch bushed side 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.

## 2.6 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 3R.

## 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. All conductors: copper.

#### 2.7.1.1 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.
- e. Digital low voltage lighting control (DLVLC) system at 24 Volts or less: Category cables in accordance with DLVLC system manufacturer requirements.

#### 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

### 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, 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 Metal-Clad Cable

UL 1569; NFPA 70, Type MC cable.

## 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.

- e. Screws: machine-type with countersunk heads in color to match finish of plate.
- f. Sectional type device plates are not be permitted.
- g. 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: white thermoplastic, except match wall finish in high bay area.
- 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 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, 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: white as per NEMA WD 1, except match wall finish in high bay area.
- 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 Split Duplex Receptacles

Provide separate terminals for each ungrounded pole. One receptacle must be controlled separately.

##### 2.12.2 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.

##### 2.12.3 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.

##### 2.12.4 Special Purpose Receptacles

Receptacles as indicated are special purpose.

## 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.
- h. Where "space only" is indicated, make provisions for future installation of breakers.
- i. Directories: indicate load served by each circuit in panelboard.
- j. Directories: indicate source of service to panelboard (e.g., Panel PA served from Panel MDP).
- l. Type directories and mount in holder behind transparent protective covering.
- m. Panelboards: listed and labeled for their intended use.
- n. 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 3R raintight 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. In addition to equipment grounding bus, provide second "isolated" ground bus, where indicated.

#### 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. Where indicated on the drawings, provide circuit breakers with shunt trip devices. 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.

#### 2.14 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.
- e. Transformer of 150 degrees C temperature rise is not acceptable.
- 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:

- 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.
- i. Use Inverter-Rated motors designed to operate with adjustable speed drive (ASD).

#### 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 Premium Efficiency Polyphase and Single-Phase Motors

Select polyphase and continuous-duty single phase motors based on high efficiency characteristics relative to typical characteristics and applications as listed in NEMA MG 10 and NEMA MG 11. In addition, continuous rated, polyphase squirrel-cage medium induction motors must meet the requirements for premium efficiency electric motors in accordance with NEMA MG 1, including the NEMA full load efficiency ratings. In exception, for 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. Electronically Commutated Motors (ECM) to have an integrated controller that senses rotor position and electronically commutates the stator windings to provide synchronous rotation. The rotor must be of a permanent magnet type supported by ball bearings to increase motor efficiency and longevity. The motor must maintain 70 percent or greater efficiency for its design application. ECM motors to comply with UL 1004-1.

#### 2.16.3 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.

#### 2.16.4 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 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.
- 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 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.
- j. 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.
- k. 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.

### 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 a separate control source. Provide terminals and terminal boards. Provide separate control disconnect switch within controller. 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)

Single, Double, or 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 GROUNDING AND BONDING EQUIPMENT

### 2.21.1 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.

#### 2.21.2 Ground Bus

Copper ground bus: provided in the electrical equipment rooms as indicated.

#### 2.21.3 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 and a Secondary bonding busbar (SBB) in all other telecommunications rooms and equipment rooms. The Primary bonding busbar (PBB) and the Secondary bonding busbar (SBB): 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 and 2 in wide for SBBs with length as indicated;
- c. Listed by a nationally recognized testing laboratory.

#### 2.22 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.

#### 2.23 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. Provide red laminated plastic label with white center core where indicated.
- f. Surface: matte finish. Corners: square. Accurately align lettering and engrave into the core.

- g. Minimum size of nameplates: one by 2.5 inches.
- h. Lettering size and style: a minimum of 0.25 inch high normal block style.

#### 2.24 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.

#### 2.25 FIRESTOPPING MATERIALS

Provide firestopping around electrical penetrations in accordance with Section 07 84 00 FIRESTOPPING.

#### 2.26 WIREWAYS

UL 870. Material: steel galvanized 16 gauge for heights and depths up to 6 by 6 inches, and 14 gauge for heights and depths up to 12 by 12 inches. Provide in length required for the application with screw-cover NEMA 1 enclosure per NEMA ICS 6.

#### 2.27 SURGE PROTECTIVE DEVICES

Provide parallel type surge protective devices (SPD) which comply with UL 1449 at the service entrance , panelboards . Provide surge protectors in a NEMA 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 )  
Neutral to ground ( N-G )  
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.

## 2.28 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 Dark Gray.
- g. Provide manufacturer's coatings for touch-up work and as specified in paragraph FIELD APPLIED PAINTING.



## 2.29 SOURCE QUALITY CONTROL

### 2.29.1 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.

## 2.30 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 IEEE C2 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 Service Entrance Identification

Service entrance disconnect devices, switches, and enclosures: labeled and identified as such.

##### 3.1.2.1 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.

#### 3.1.3 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. 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.

#### 3.1.3.1 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.

#### 3.1.3.2 Metal-Clad Cable

Install in accordance with NFPA 70, Type MC cable. Allowed only in dry, exposed locations and allowed in cable trays.

#### 3.1.4 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. Run conduits under floor slab as if exposed.

##### 3.1.4.1 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.

##### 3.1.4.2 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.

-

#### 3.1.4.3 Restrictions Applicable to Flexible Conduit

Use only as specified in paragraph FLEXIBLE CONNECTIONS.

#### 3.1.4.4 Underground Conduit

Plastic-coated rigid steel; plastic-coated steel IMC; PVC, Type EPC-40  
Plastic coating: extend minimum 6 inches above floor.

#### 3.1.4.5 Conduit for Circuits Rated Greater Than 600 Volts

Rigid metal conduit or IMC only.

#### 3.1.4.6 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.

#### 3.1.4.7 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.

#### 3.1.4.8 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.

#### 3.1.4.9 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 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.

#### 3.1.4.10 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.

#### 3.1.4.11 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.

#### 3.1.4.12 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 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.

#### 3.1.4.13 Telecommunications and Signal System Pathway

Install telecommunications pathway in accordance with TIA-569 and Division 27.

#### 3.1.5 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, 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.3.1.5.1

#### 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.

##### 3.1.5.1.1 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.

##### 3.1.5.2 Pull Boxes

Construct of at least minimum size required by NFPA 70 of code-gauge aluminum or galvanized sheet steel, and compatible with nonmetallic raceway systems, 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.

##### 3.1.5.3 Extension Rings

Extension rings are not permitted for new construction. Use only on existing boxes in concealed conduit systems where wall is furred out for new finish.3.1.6 Mounting Heights

Mount panelboards, enclosed 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 and handicapped telecommunications stations 48 inches above finished floor. Mount receptacles and telecommunications outlets 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

outletsto center of device or outlet.

### 3.1.7 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.

#### 3.1.7.1 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.

#### 3.1.8 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.

#### 3.1.9 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.

### 3.1.10 Electrical Penetrations

Seal openings around electrical penetrations through fire resistance-rated walls, partitions, floors, or ceilings in accordance with Section 07 84 00 FIRESTOPPING.

### 3.1.11 Grounding and Bonding

Provide in accordance with NFPA 70 and NFPA 780. Ground exposed, non-current-carrying metallic parts of electrical equipment, access flooring support system, 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.

#### 3.1.11.1 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, 3 additional rods, spaced on center. Spacing for additional rods must be a minimum of 10 feet, or if sectional type rods are used, 2 additional sections may be coupled and driven with the first rod. 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.

#### 3.1.11.2 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.

#### 3.1.11.3 Ground Bus

Provide a copper ground bus in the electrical equipment rooms as indicated. Noncurrent-carrying metal parts of transformer neutrals and other 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. For raised floor equipment rooms in computer and data processing centers, provide a minimum of four, one at each corner, ground buses connected to the building grounding system. Use bolted connections in lieu of thermoweld, so they can be changed as required by additions and alterations.

#### 3.1.11.4 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.

#### 3.1.11.5 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. Provide a Secondary bonding busbar (SBB) in all other telecommunications rooms and telecommunications equipment rooms. Install the SBB as close to the telecommunications room panelboard as practicable, when equipped. Where a panelboard for telecommunications equipment is not installed in the telecommunications room, locate the SBB near the backbone cabling and associated terminations. In addition, locate the SBB to provide for the shortest and straightest routing of the grounding conductors. Where a panelboard for telecommunications equipment is located within the same room or space as a SBB, bond that panelboard's alternating current equipment ground (ACEG) bus (when equipped) or the panelboard enclosure to the SBB. 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. Provide a telecommunications bonding backbone (TBB) that originates at the PBB extends throughout the building using the telecommunications backbone pathways, and connects to the SBBs in all telecommunications rooms and equipment rooms. Install the TBB conductors such that they are protected from physical and mechanical damage. The TBB conductors should be installed without splices and routed in the shortest possible straight-line path. Make the bonding conductor between a TBB and a SBB continuous. Where splices are necessary, the number of splices should be a minimum. Make the splices accessible and located in telecommunications spaces. Connect joined segments of a TBB using exothermic welding, irreversible compression-type connectors, or equivalent. Install all joints to be adequately supported and protected from damage. Whenever two or more TBBs are used within a multistory building, bond the TBBs together with a grounding equalizer (GE) at the top floor and at a minimum of every third floor in between. Do not connect the TBB and GE to the pathway ground, except at the PBB or the SBB.

- c. Telecommunications Grounding Connections: Telecommunications grounding connections to the PBB or SBB: 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 or SBB to the PBB or SBB respectively. In a metal frame (structural steel) building, where the steel framework is readily accessible within the room; bond each PBB and SBB 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.

#### 3.1.12 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.

#### 3.1.13 Government-Furnished Equipment

Contractor make connections to 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.

#### 3.1.14 Repair of Existing Work

Perform repair of existing work as follows:

#### 3.1.14.1 Workmanship

Lay out work in advance. Exercise care where cutting, channeling, chasing, or drilling of floors, walls, partitions, ceilings, or other surfaces is necessary for proper installation, support, or anchorage of conduit, raceways, or other electrical work. Repair damage to buildings, piping, and equipment using skilled craftsmen of trades involved.

#### 3.1.15 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. Where field painting of enclosures for panelboards, load centers or the like is specified to match adjacent surfaces, to correct damage to the manufacturer's factory applied coatings, or to meet the indicated or specified safety criteria, provide manufacturer's recommended coatings and apply in accordance to manufacturer's instructions.

#### 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 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

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 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, are as defined in IEEE 100.

1.3 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. Submittals with an "S" are for inclusion in the Sustainability Notebook, 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-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

Request for Settings; G

Service Entrance Available Fault Current Label; G

1.4 QUALITY ASSURANCE

1.4.1 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.

1.4.2 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.

1.4.3 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.

#### 1.4.4 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.

##### 1.4.4.1 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.

##### 1.4.4.2 Material and Equipment Manufacturing Date

Products manufactured more than one year prior to date of delivery to site are not acceptable.

#### 1.5 MAINTENANCE

##### 1.5.1 Switchboard Operation and Maintenance Data

Submit Operation and Maintenance Manuals in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

##### 1.5.2 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.

#### 1.6 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: 1200 amperes.
- 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 and aligned as indicated.
- b. All circuit breakers: front accessible.
- c. Rear aligned switchboards: front accessible load connections.
- d. 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.
- e. 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.
- b. Enclosure: bolted together with removable bolt-on side and rear covers.
- e. Base: includes any part of enclosure that is within 3 inches of concrete pad.
- g. Paint color: ASTM D1535 light gray No. 61 or No. 49 over rust inhibitor.

#### 2.2.2.2 Bus Bars

Provide the following:

- a. Bus bars: copper with silver-plated contact surfaces or aluminum with tin-plated contact surfaces.
  - (1) Phase bus bars: uninsulated.
  - (2) Neutral bus: rated 100 percent of the main bus continuous current rating.
- 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 an individually mounted fixed.

#### 2.2.2.4 Distribution Sections

Provide the distribution sections consisting of molded-case circuit breakers as indicated.

#### 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 and standard rated branch breakers, manually operated, low voltage molded-case circuit breaker, with a short-circuit current rating of as indicated at 480volts.
- b. Breaker frame size: as indicated.
- c. Series rated circuit breakers are unacceptable.

#### 2.2.4 Electronic Trip Units

Equip main and distribution breakers with a solid-state tripping system consisting of three current sensors and a microprocessor-based trip unit that provides true rms sensing adjustable time-current circuit protection. Include the following:

- a. Current sensors ampere rating: the same as the breaker frame rating.
- b. Trip unit ampere rating: as indicated.
- c. Ground fault protection: as indicated.
- d. Electronic trip units: provide additional features:
  - (1) Breakers: include long delay pick-up and time settings, and LED indication of cause of circuit breaker trip.
  - (2) Main breakers: include short delay pick-up and time settings and, instantaneous settings and ground fault settings.
  - (3) Distribution breakers: include short delay pick-up and time settings, instantaneous settings.
  - (4) Main Breakers: include a digital display for phase and ground current.
  - (5) Main Breakers: include a digital display for watts, vars, VA, kWh, kvarh, and kVAh.
  - (6) Main Breakers: include a digital display for phase voltage, and percent THD voltage and current.
  - (7) For electronic trip units that are rated for or can be adjusted to 1,200 amperes or higher, provide arc energy reduction capability with an energy-reducing maintenance switch with local status indicator.

#### 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.

## 2.5.3 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 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.

## 2.7 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.

## 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 5 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 request for 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.
- (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 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.



### 3.5.1.3 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.

### 3.5.1.4 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.

### 3.5.1.5 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.

### 3.5.2 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 27 13.10 30

ELECTRIC METERS  
**10/07, 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.

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 C37.90.1 | (2013) Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus |
| IEEE C57.13   | (2016) Standard Requirements for Instrument Transformers   |

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

- |               |   |
|---------------|---|
| IEC 61000-4-5 | (2017) Electromagnetic Compatibility (EMC) - Part 4-5: Testing and Measurement Techniques - Surge Immunity Test                             |
| IEC 62053-22  | (2020) Electricity Metering Equipment (A.C.) - Particular Requirements - Part 22: Static Meters for Active Energy (Classes 0,2 S and 0,5 S) |

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

- |             |  |
|-------------|--|
| ANSI C12.18 | (2006; R 2023) Protocol Specification for ANSI Type 2 Optical Port                             |
| ANSI C12.20 | (2015; E 2018) Electricity Meters - 0.1, 0.2, and 0.5 Accuracy Classes                         |
| 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 |
|---------|---|

## 1.2 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in this specification and on the drawings are as defined in IEEE 100.

## 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. Submittals with an "S" are for inclusion in the Sustainability Notebook, in conformatnce to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

- a. Provide the following in the maintenance manual:
  1. Condensed description of how the equipment operates.
  2. Block diagram indicating major assemblies.
  3. Troubleshooting information
  4. Preventive maintenance.
  5. Spare parts information.
- b. Provide operation and maintenance manuals required by submittal item "SD-10 Operation and Maintenance Data."

SD-02 Shop Drawings

SD-03 Product Data

Power Meters; G

Current Transformers; G

Potential Transformer; G

Communications Module; G

Protocol Modules; G

Data Recorder; G

Modem; G

Include manufacturer's information for each component, device, and accessory provided with the meter, protocol module or communications module.

SD-06 Test Reports

Acceptance Checks and Tests; G

SD-10 Operation and Maintenance Data

Power Meters; G

Communications Module; G

Protocol Modules; G

Data Recorder; G

Modem; G

SD-11 Closeout Submittals

System Function Verification; G

#### 1.4 QUALITY ASSURANCE

##### 1.4.1 Installation Drawings

Drawings indicate but are not limited to the following:

- a. Elementary diagrams and wiring diagrams with terminals identified of advanced meter, current transformers, potential transformers, protocol modules, communications modules, Ethernet connections, .
- b. One-line diagram, including meters, switch(es), current transformers, potential transformers, protocol modules, communications modules, Ethernet connections, .

##### 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. Provide products that have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year period includes applications of equipment and materials under similar circumstances and of similar size. Provide product that has 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 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.

##### 1.4.3 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.

##### 1.4.4 Material and Equipment Manufacturing Data

Do not use products manufactured more than 2 years prior to date of delivery to site, unless specified otherwise.

#### 1.5 WARRANTY

Provide equipment items 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.

## 1.6 SYSTEM DESCRIPTION

### 1.6.1 System Requirements

The metering and reading system, consisting of commercial, off-the-shelf meters, protocol modules, communications modules, and communication channels, will be used to record the electricity consumption and other values as described in the sections that follow and as shown on the drawings.

### 1.6.2 Selection Criteria

Metering components are part of a system that includes the physical meter, data recorder function and communications (modem) method. Include sufficient metering components to measure the electrical parameters identified and to store and communicate the values as required in the following sections for every building site identified. Verify that the metering system installed on any building site is compatible with the facility-wide communication and meter-reading protocol system. Contractor must connect the metering system to the facility-wide energy and utility monitoring and control system.

## PART 2 PRODUCTS

### 2.1 POWER METERS

#### 2.1.1 Physical and Common Requirements

- a. Metering system components shall be installed on the secondary side of the facility transformer. Coordinate installation of the current transformers and potential transformers with the utility provider..
- b. Power meter must be socket-mount design.
- c. If existing meter base is usable, the meter base determines meter form factor. If a new meter is being installed, use meter and base form factor of 9S.
- d. Provide meter consisting of a Class 20, transformer rated design.
- e. Provide meter that is rated for use at temperature from -40 degrees Centigrade to +70 degrees Centigrade.
- f. Meter must have NEMA 3R enclosure for surface mounting.
- g. Surge withstand must conform to IEEE C37.90.1.
- h. Provide meter with a standard 4 -year warranty.
- i. Provide meter in compliance with IEC 62053-22 (Part 21: Static Meter for Active Energy, classes 0.2S and 0.5S), certified by a qualified third party test laboratory.

#### 2.1.2 Voltage Requirements

- a. Furnish meter that is capable of connection to the service voltage phases and magnitude being monitored. If the meter is not rated for the service voltage, provide suitable potential transformers to send

an acceptable voltage to the meter.

- b. Provide meter that is capable of connection to the service voltage indicated on the drawings.
- c. Provide meter that accepts independent voltage inputs from each phase and is auto-ranging over the full range of input voltages.
- d. Optically isolate voltage input to 2500 volts DC from signal and communications outputs. Use components meeting or exceeding IEEE C37.90.1 (Surge Withstand Capability).
- e. The Contractor is responsible for determining the actual voltage ratio of each potential transformer. Provide transformer conforming to IEEE C57.13 and the following requirements.
  1. Type: Dry type, of two-winding construction.
  2. Weather: Outdoor or Indoor rated for the application.
  3. Frequency: Nominal 60Hz, 50Hz for those bases that operate on 50Hz.
  4. Accuracy: Plus or minus 0.3% at 60Hz or 0.3% for those systems that operate at 50Hz.

#### 2.1.3 Current Requirements

- a. Accept independent current inputs from each phase. Install current transformer with a full load rating as shown in the drawings.
- b. Provide single ratio current transformer with an Accuracy Class of 0.3 with a maximum error of +/- 0.3% at 5.0 amps.
- c. Current transformer must have:
  1. Insulation Class: Provide 600 volt and below current transformers rated at 10 KV BIL. Provide current transformers for 2400 and 4160 volt service rated at 25 KV BIL.
  2. Frequency: Nominal 60Hz, 50Hz for bases that operate on 50Hz.
  3. Burden: Select burden class for the load.
  4. Phase Angle Range: 0 to 60 degrees.
- d. Provide meter that accepts current input from standard instrument transformers (5A secondary current transformers.)
- e. Current inputs must have a continuous rating in accordance with IEEE C57.13.
- f. Provide multi-ratio current transformer where indicated with a top range equal to or greater than the actual load. The Contractor is responsible for determining the actual ratio of each transformer. Provide current transformer conforming to IEEE C57.13.

#### 2.1.4 Electrical Measurements

Measure and report the following quantities:



- a. Kilowatt-hours ("kWh" in Metering Systems Schedule) of consumption. Cumulative.
- b. Kilowatts of demand ("kW" in Metering Systems Schedule). Peak average over a selectable demand interval between 5 and 60 minutes (typically 15 minutes).
- c. Reactive power ("kVAR" in Metering Systems Schedule). Measured over the same interval as the peak kW reading.
- d. Power factor ("PF" in Metering Systems Schedule). Measured over the same interval as the peak kW reading.
- e. Time of use consumption ("TOU" in Metering Systems Schedule). Kilowatt-hours recorded separately for each period set by programming into the meter. Time periods must be capable of being changed without removal from service. The meter must internally record and store Time of Use data.
  1. Four (4) minimum TOU Rates (Registers)
  2. Twenty (20) Year Calendar
  3. Two (2) minimum seasons per year
- f. Interval recording ("IR"). Record kilowatt-hours for each 15 minute interval and accumulate for 30 days. Memory for recording the interval readings must be internal to the meter and ANSI C12.19 compliant. Provide time-stamped readings for every measured parameter.
- g. Meter readings must be true RMS.

#### 2.1.5 Meter Accuracy

Provide the following accuracies. Measure accuracies as percent of reading at standard meter test points.

- a. Provide power meter meeting ANSI C12.20 for Class 0.2 and IEC 62053-22 accuracy requirements.

#### 2.1.6 An on the Meter Display, Output and Reading Capabilities

Include the following output signals.

- a. The meter will have a face display plate and will display every electrical parameter indicated to be recorded. Do not require meters to indicate interval data collected in a data logger with a communications output feature. Display peak values, instantaneous and cumulative values.
- b. Include optical output port capable of 9600 bps communication with a hand-held reading device. Provide optical device that is compatible with ANSI C12.18
- c. Include output options for analog milliamp signals.
- d. Provide meter with two channels of analog output, 0-1mA or 4-20mA, for positive watt/hour readings.

- e. Include output option for pulse output. KYZ pulse output related to kWatts/HR.
- f. Provide meter with two form C, dry contact relay outputs for alarm or control.

#### 2.1.7 Installation Methods

- a. Transformer mounted (XFMR)
  - 1. Locate meter base outside on the secondary side of the pad-mounted transformer.
- b. Stand-mounted adjacent to transformer
  - 1. Mount meter base on a structural steel pole approximately 4 feet from the transformer pad.
- c. Common features.
  - 1. PTs (if required for proper voltage range) and physically connect CTs to the service entrance cables inside the service entrance disconnect enclosure.

#### 2.1.8 Disconnecting Switches

- a. Provide disconnecting wiring blocks between the current transformer and the meter. Build a shorting mechanism into the wiring block to allow the current transformer wiring to be changed without removing power to the transformer. Locate the wiring blocks where they are accessible without the necessity of disconnecting power to the transformer. For multi-ratio current transformers, provide a shorting block from each tap to the common lead.
- b. Equip voltage-monitoring circuits with disconnect switches to isolate the meter base or socket from the voltage source.

#### 2.1.9 Meter Programming

- a. Provide power meter that is programmable by software supplied by the meter manufacturer.
- b. Provide user-friendly software with Windows-compatible interface.
- c. Operate software on Windows operating systems.
- d. Provide software that allows the user to configure the meter, troubleshoot meter, query and display meter parameters and configuration data and stored values.
- e. Provide meter firmware that is upgradeable through one of the communications ports without removing the unit from service.

## 2.2 COMMUNICATIONS

### 2.2.1 Communications Methods

#### 2.2.1.1 Optical Port

Communicate with a hand-held reading device according to the following requirements.

##### a. Communications standards

1. ANSI C12.18
2. MV90 protocol
3. ANSI C12.20

##### b. Read operations

1. Current kWh values
2. Demand (kW) values since last reset
3. Last reset value
4. Meter status

##### c. Write operations

1. Meter setup

#### 2.2.1.2 Serial Port

Provide serial port for connection to modem module where required in this specification.

##### a. On-Board serial port types

1. RS232
2. \

#### 2.2.1.3 Ethernet

For those meters using the Ethernet, send logged information using open standard Internet Protocols.

##### a. On-board Ethernet port support

1. HTTP
2. SMTP

(a) Modbus

##### b. Distribute stored data by

1. FTP

### 2.2.2 Communications Protocols and Methods

Use communications protocols and methods that are native to the meter. Provide communications module(s) as required to accomplish the following.

- a. Include an IR port for communication to external devices such as handheld readers that support a minimum speed of 9600 baud.
- b. Include one RS-232 or one RS-485 digital communication port. Provide user configurable port with regard to speed, protocol, address, and other communications parameters that support a minimum communication speed of 9600 baud for the RS232 port.
- c. Provide meter with a port that can be configured as a 10/100 Base-T Ethernet port
  1. A communication module that converts serial RS232 or RS485 to Ethernet will be acceptable.
- d. Auto Answer minimum 1200 baud internal modem. Include automatic data buffering to provide faster, more reliable communications and the ability to automatically answer on a connected line.
- e. Equip meter with one pulse output channel that can be configured for operation as KYZ pulse output.

### 2.2.3 Communications Channels Surge Protection

Protect communications equipment against surges induced on its communications channels. Protect communication interfaces to all field equipment to meet the requirements of IEEE C37.90.1 or the requirements of IEC 61000-4-5, test level 4, while the equipment is operating. Do not use fuses for surge protection. For metallic cables and conductors which serve as communications channels between buildings, install surge protection at equipment rated for the application at each end, within 3 feet of the building cable entrance. Provide surge protectors meeting the requirements of the applicable extension of ANSI C62 (for example, ANSI C62.61).

## 2.3 METER DATA PROTOCOL

Provide power meters that have communicating data protocols native or provide in supplemental modules to communicate with the communications methods that follow.

### 2.3.1 Open Protocol

Support the following open protocols. Verify that the meter native protocol is consistent with the facility data recording and communication and data storage system. Provide additional converters and modules as required for a complete measurement, recording, communicating and data storage system.

- a. Provide meter that is fully supported by MV-90 software system or existing AMR software that is MV-90 compatible.
- b. For systems that use proprietary software, an alternative, competitive software system must be available.

Systems capable of using more than one brand of commercially available meters are expected. In addition, if proprietary meter reading software is used, meters are to be capable of being read by more than one manufacturer's software.

### PART 3 EXECUTION

#### 3.1 INSTALLATION

Perform electrical installations conforming to IEEE C2, NFPA 70, and to the requirements specified herein. Provide new equipment and materials unless indicated or specified otherwise.

##### 3.1.1 Scheduling of Work and Outages

The Contract Clauses govern regarding permission for power outages, scheduling of work, coordination with Government personnel, and special working conditions.

#### 3.2 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 FIELD QUALITY CONTROL

##### 3.3.1 Performance of Acceptance Checks and Tests

###### 3.3.1.1 Meter Assembly

###### a. Visual and mechanical inspection

1. Compare equipment nameplate data with specification and approved shop drawings.
2. Inspect physical and mechanical condition.
3. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method.
4. Verify grounding of metering enclosure.
5. Verify the presence of surge arresters.
6. Verify that the CT ratio and the PT ratio are properly included in the meter multiplier or the programming of the meter.

###### b. Electrical tests

1. Calibrate watthour meters according to manufacturer's published data.
2. Verify that correct multiplier has been placed on face or meter where applicable.

3. Prior to system acceptance, the Contractor will demonstrate and confirm the meter is properly wired and is displaying correct and accurate electrical information.

#### 3.3.1.2 Current Transformers

##### a. Visual and mechanical inspection

1. Compare equipment nameplate data with specification and approved shop drawings.
2. Inspect physical and mechanical condition.
3. Verify correct connection.
4. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method.
5. Verify that 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 test.
3. Perform a polarity test.
4. Perform a ratio-verification test.

#### 3.3.1.3 Potential Transformers

##### a. Visual and mechanical inspection

1. PT's are rigidly mounted.
2. PT's are correct voltage.
3. Verify that adequate clearances exist between primary and secondary circuit.

##### b. Electrical tests

1. Perform a ratio-verification test.

#### 3.3.2 Follow-Up System Function Verification

Upon completion of acceptance checks and tests, the show by demonstration in service that circuits and devices are in good operating condition and properly performing the intended function. As an exception to requirements stated elsewhere in the contract, give the Contracting Officer 5 working days' advance notice of the dates and times of checking and testing.

#### 3.3.3 Training

Conduct a training course for meter configuration, operation, and

maintenance of the system as specified. Orient the training for all components and systems installed under this contract. Deliver training manuals for 6 trainees with two additional copies delivered for archiving at the project site. Furnish all audiovisual equipment and all other training materials and supplies. A training day is defined as eight 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. For guidance in planning the required instruction, assume that attendees have a high school education or equivalent, and are familiar with utility systems. Obtain approval of the planned training schedule from the Government at least 30 days prior to the training.

- a. Training: Teach the course at the project site within thirty days after completion of the installation for a period of one day(s). A maximum of 6 personnel will attend the course. The training includes:
1. Physical layout of each piece of hardware.
  2. Meter configuration, troubleshooting and diagnostics procedures.
  3. Repair instructions.
  4. Preventive maintenance procedures and schedules.
  5. Testing and calibration procedures.

-- End of Section --

SECTION 26 29 23

ADJUSTABLE SPEED DRIVE (ASD) SYSTEMS UNDER 600 VOLTS  
**02/20, CHG 1: 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.

EUROPEAN COMMITTEE FOR STANDARDIZATION (CEN/CENELEC)

EN 61800-3 (2017) Requirements for the Control of  
Electromagnetic Interference  
Characteristics of Subsystems and Equipment

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 519 (2022) Standard for Harmonic Control in  
Electrical Power Systems

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

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 61000-3-12 (2012) Electromagnetic Compatibility (EMC)  
- Part 3-12: Limits - Limits for harmonic  
currents produced by equipment connected  
to public low-voltage systems with input  
current >16 A and <math>\leq 75\text{ A}</math> per phase

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250 (2020) Enclosures for Electrical Equipment  
(1000 Volts Maximum)

NEMA ICS 1 (2022) Standard for Industrial Control and  
Systems: General Requirements

NEMA ICS 3.1 (2019) Guide for the Application,  
Handling, Storage, Installation and  
Maintenance of Medium-Voltage AC  
Contactors, Controllers and Control Centers

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

NEMA ICS 7 (2020) Adjustable-Speed Drives



NEMA ICS 7.2	(2015) Application Guide for AC Adjustable Speed Drive Systems
NEMA MG 1	(2021) Motors and Generators
NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)	
NFPA 70	(2023; ERTA 7 2023; TIA 23-15) National Electrical Code
U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)	
47 CFR 15	Radio Frequency Devices
UNDERWRITERS LABORATORIES (UL)	
UL 489	(2016; Rev 2019) UL Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
UL 61800-5-1	(2016) Adjustable Speed Electrical Power Drive Systems - Part 5-1: Safety Requirements - Electrical, Thermal and Energy

## 1.2 RELATED REQUIREMENTS

Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM applies to this section with additions and modifications specified herein.

## 1.3 SYSTEM DESCRIPTION

### 1.3.1 Performance Requirements

#### 1.3.1.1 Electromagnetic Interference Suppression

Computing devices, as defined by 47 CFR 15 and EN 61800-3 rules and regulations, must be certified to comply with the requirements for class A computing devices and labeled.

#### 1.3.1.2 Electromechanical and Electrical Components

Ensure electrical and electromechanical components of the Adjustable Speed Drive (ASD) do not cause electromagnetic interference to adjacent electrical or electromechanical equipment while in operation.

### 1.3.2 Electrical Requirements

#### 1.3.2.1 Power Line Surge Protection

IEEE C62.41.1 and IEEE C62.41.2, IEEE 519, IEC 61000-3-12 Control panel must have surge protection, included within the panel to protect the unit from damaging transient voltage surges. Surge protective device must be mounted near the incoming power source and properly wired to all three phases and ground. Fuses must not be used for surge protection.

#### 1.3.2.2 Sensor and Control Wiring Surge Protection

I/O functions as specified must be protected against surges induced on

control and sensor wiring installed outdoors and as shown. Test the inputs and outputs in both normal mode and common mode using the following two waveforms:

- a. A 10 microsecond by 1000 microsecond waveform with a peak voltage of 1500 volts and a peak current of 60 amperes.
- b. An 8 microsecond by 20 microsecond waveform with a peak voltage of 1000 volts and a peak current of 500 amperes.

#### 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 Notebook, 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

- Schematic Diagrams; G
- Interconnecting Diagrams; G
- Installation Drawings; G
- As-Built Drawings; G

##### SD-03 Product Data

- Adjustable Speed Drives; G
- Wires and Cables
- Equipment Schedule

##### SD-06 Test Reports

- ASD Test
- Performance Verification Tests
- Endurance Test

##### SD-08 Manufacturer's Instructions

- Installation instructions

##### SD-09 Manufacturer's Field Reports

- ASD Test Plan; G
- Standard Products

##### SD-10 Operation and Maintenance Data

- Adjustable Speed Drives, Data Package 4

## 1.5 QUALITY ASSURANCE

### 1.5.1 Schematic Diagrams

Submit diagrams showing circuits and device elements for each replaceable module. Schematic diagrams of printed circuit boards are permitted to group functional assemblies as devices, provided that sufficient information is provided for government maintenance personnel to verify proper operation of the functional assemblies.

### 1.5.2 Interconnecting Diagrams

Show interconnections between equipment assemblies, and external interfaces, including power and signal conductors. Include for enclosures and external devices.

### 1.5.3 Installation Drawings

Show floor plan of each site, with ASD's and motors indicated. Indicate ventilation requirements, adequate clearances, and cable routes. Submit drawings for government approval prior to equipment construction or integration. Immediately record modifications to original drawings made during installation for inclusion into the as-built drawings.

### 1.5.4 Equipment Schedule

Provide schedule of equipment supplied. Schedule must provide a cross reference between manufacturer data and identifiers indicated in shop drawings. Schedule must include the total quantity of each item of equipment supplied and data indicating compatibility with motors being driven. For complete assemblies, such as ASD's, provide the serial numbers of each assembly, and a sub-schedule of components within the assembly. Provide recommended spare parts listing for each assembly or component.

### 1.5.5 Installation Instructions

Provide installation instructions issued by the manufacturer of the equipment, including notes and recommendations, prior to shipment to the site. Provide operation instructions prior to acceptance testing.

### 1.5.6 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.

## 1.6 DELIVERY AND STORAGE

Store delivered equipment to protect from the weather, humidity and temperature variations, dirt and dust, or other contaminants.

## 1.7 WARRANTY

The complete system must be warranted by the manufacturer for a period of one year . Repair or replace any component failing to perform its function as specified and documented at no additional cost to the Government. Items repaired or replaced must be warranted for an additional period of at least one year from the date that it becomes functional again, as specified in FAR 52.246-21 Warranty of Construction.

## 1.8 MAINTENANCE

### 1.8.1 Operation and Maintenance Data

Provide in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. Provide service and maintenance information including preventive maintenance, assembly, and disassembly procedures. Include electrical drawings from electrical general sections. Provide additional information necessary to provide complete operation, repair, and maintenance information, detailed to the smallest replaceable unit. Include copies of as-built submittals. Provide routine preventative maintenance instructions, and equipment required. Provide instructions on how to modify program settings, and modify the control program. Provide instructions on drive adjustment, trouble-shooting, and configuration. Provide instructions on process tuning and system calibration.

### 1.8.2 Maintenance Support

During the warranty period, provide on-site, on-call maintenance services by drive manufacturer's personnel on the following basis: The service must be on a per-call basis with 36 hour response. Contractor is responsible for the maintenance of all hardware and software of the system during the warranty period. Various personnel of different expertise must be sent on-site depending on the nature of the maintenance service required. Costs must include travel, local transportation, living expenses, and labor rates of the service personnel while responding to the service request. The provisions of this Section are not in lieu of, nor relieve the Contractor of, warranty responsibilities covered in this specification. Should the result of the service request be the uncovering of a system defect covered under the warranty provisions, all costs for the call, including the labor necessary to identify the defect, must be borne by the Contractor.

### 1.8.3 Technical Support

Provide the ASDs with manufacturer's technical telephone support in English, readily available during normal working hours.

## PART 2 PRODUCTS

### 2.1 ADJUSTABLE SPEED DRIVES (ASD)

Provide adjustable speed drive to control the speed of induction motor(s). The ASD must include the following minimum functions, features and ratings.

- a. Input circuit breaker per UL 489 with a minimum of 10,000 amps symmetrical interrupting capacity and door interlocked external operator.
- b. A converter stage per UL 61800-5-1 must change fixed voltage, fixed frequency, ac line power to a fixed dc voltage. The converter must utilize a full wave bridge design incorporating diode rectifiers. Silicon Controlled Rectifiers (SCR) are not acceptable. The converter must be insensitive to three phase rotation of the ac line and must not cause displacement power factor of less than .95 lagging under any speed and load condition.
- c. An inverter stage must change fixed dc voltage to variable frequency, variable ac voltage for application to a standard NEMA MG 1 Part 30 motor designed for use with adjustable frequency power supplies. Switch the inverter to produce a sine coded pulse width modulated (PWM) output waveform.
- d. The ASD shall be capable of supplying 110 percent of rated full load current for one minute at maximum ambient temperature.
- e. The ASD must be designed to operate from a 480 volt, plus or minus 10 percent, three phase, 60 Hz supply, and control motors with a corresponding voltage rating.
- f. Acceleration and deceleration time must be independently adjustable from one second to 60 seconds.

Required deceleration time may be achieved using not only dynamic braking resistor but with other methods described in NEMA ICS 7.2-2015 paragraph 5.2.5.

- g. Adjustable full-time current limiting must limit the current to a preset value which must not exceed 110 percent of the controller rated current. The current limiting action must maintain the V/Hz ratio constant so that variable torque can be maintained. Short time starting override must allow starting current to reach 175 percent of controller rated current to maximum starting torque.
- h. The controllers must be capable of producing an output frequency over the range of 3 Hz to 60 Hz (20 to one speed range), without low speed cogging. Over frequency protection must be included such that a failure in the controller electronic circuitry must not cause frequency to exceed 110 percent of the maximum controller output frequency selected.
- i. Minimum and maximum output frequency must be adjustable over the following ranges: 1) Minimum frequency 3 Hz to 50 percent of maximum selected frequency; 2) Maximum frequency 40 Hz to 60 Hz.
- j. The controller efficiency at any speed must not be less than 96 percent.
- k. The controllers must be capable of being restarted into a motor coasting in the forward direction without tripping.
- l. Protection of power semiconductor components must be accomplished without the use of fast acting semiconductor output fuses. Subjecting

the controllers to any of the following conditions must not result in component failure or the need for fuse replacement:

- (1) Short circuit at controller output
  - (2) Ground fault at controller output
  - (3) Open circuit at controller output
  - (4) Input undervoltage
  - (5) Input overvoltage
  - (6) Loss of input phase
  - (7) AC line switching transients
  - (8) Instantaneous overload
  - (9) Sustained overload exceeding 115 percent of controller rated current
  - (10) Over temperature
  - (11) Phase reversal
- m. Solid state motor overload protection must have sensor in each phase, Class 10 tripping characteristic selected to protect motor against voltage and current unbalance and single phasing, .
- n. Include slip compensation circuit that will sense changing motor load conditions and adjust output frequency to provide speed regulation of NEMA MG 1 Part 30 designed for use with adjustable frequency power supplies motors to within plus or minus 0.5 percent of maximum speed without the necessity of a tachometer generator.
- o. The ASD must be factory set for manual restart after the first protective circuit trip for malfunction (overcurrent, undervoltage, overvoltage or overtemperature) or an interruption of power. The ASD must be capable of being set for automatic restart after a selected time delay. If the drive faults again within a specified time period (adjustable 0-60 seconds), a manual restart will be required. Provide Bidirectional AutospeedSearch capable of starting the ASD into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.
- p. The ASD must include external fault reset capability. All the necessary logic to accept an external fault reset contact must be included.
- q. Provide critical speed lockout circuitry to prevent operating at frequencies with critical harmonics that cause resonant vibrations. The ASD must have a minimum of three user selectable bandwidths.
- r. Provide properly sized NEMA rated by-pass and isolation contactors to enable operation of motor in the event of ASD failure and for safety transfers motor between power converter output and bypass circuit using a field-selectable automatic and manual bypass mode. Install

mechanical and electrical interlocks between the by-pass and isolation contactors. Provide a selector switch and transfer delay timer. Motor overload and short circuit protective features must remain in use during the bypass mode.

- s. Each individual ASD must meet the following Total Harmonic Distortion (THD) requirements at the input terminals to the factory assembly of the ASD or at the load disconnecting means serving the ASD and filter assembly. These measurements should be taken with the drive set at 90 percent frequency (rpms) and the motor under a minimum of 50 percent demand.
  - (1) The Voltage THD should not exceed 2.0 percent THD.
  - (2) The Current THD should not exceed 15.0 percent THD.
  - (3) If the standard factory ASD does not meet or exceed these requirements the factory must install appropriate equipment (Harmonic Traps, Filters, different Drive technology, etc.) to mitigate the distortion to assure performance of the VFD is within the limits.
  - (4) These tests should be performed at the Manufacturers Laboratory facilities and submitted as part of the Product Data Submittals, in order to prevent the necessity of adding mitigation equipment in the field. If the requirements listed above are met, IEEE 519 will also be met.
- t. Minimum Operating Conditions. Designed and constructed ASD's to operate within the following service conditions:
  - (1) Ambient Temperature Rating: 0 to 120 degrees F.
  - (2) Non-condensing relative humidity rating: less than 95 percent.
  - (3) Ambient rating: Not exceed 3,300 feet.

#### 2.1.1.1 ASD for HVAC Application

ASDs must have the following features:

- a. A local operator control providing the following functions:
  - (1) Remote/Local operator selection with password access.
  - (2) Run/Stop and manual speed commands.
  - (3) All programming functions.
  - (4) Scrolling through all display functions.
- b. A local operator control panel with the following data displayed:
  - (1) ASD status.
  - (2) Frequency.
  - (3) Motor RPM.

- (4) Phase current.
- (5) Scrolling through all display functions.
- (6) Fault diagnostics in descriptive text.
- (7) All programmed parameters.
- c. Standard PI loop controller with input terminal for controlled variable and parameter settings.
- d. User interface terminals for remote control of ASD speed, speed feedback, and an isolated form C SPDT relay, which energizes on a drive fault condition.
- e. An isolated form C SPDT auxiliary relay which energizes on a run command.
- f. An adjustable carrier frequency with 16 KHz minimum upper limit.
- g. A built-in or external line reactor with 3 percent minimum impedance to protect the DC bus capacitors and rectifier section diodes.
- h. Historical logging information and displays:
  - (1) Running log of total power versus time.
  - (2) Total run time.
  - (3) Fault log, maintaining last four faults with time and data stamp for each.
  - (4) .
- i. The ASD must be capable of automatic control by a remote 4-20 mA or 0 to 10 VDC signal, by BACnet network command, or manually by the ASD control panel.
- j. ASDs must include the following operator programmable parameters:
  - (1) Upper and lower limit frequency.
  - (2) Acceleration and deceleration rate.
  - (3) Variable torque volts per Hertz curve.
  - (4) Starting voltage level.
  - (5) Starting frequency level.
  - (6) Display speed scaling.
  - (7) Enable/disable soft stall feature.
  - (8) Motor overload level.
  - (9) Motor stall level.
  - (10) Jump frequency and hysteresis band.



(11) PWM carrier frequency.

k. ASD must have the following protective features:

- (1) An electronic adjustable inverse time current limit with consideration for additional heating of the motor at frequencies below 45Hz, for the protection of the motor.
- (2) An electronic adjustable soft stall feature, allowing the ASD to lower the frequency to a point where the motor will not exceed the full-load amperage when an overload ASD will automatically return to the requested frequency when load conditions permit.
- (3) A separate electronic stall at 110 percent ASD rated current, and a separate hardware trip at 190 percent current.
- (4) The ability to shut down if inadvertently started into a rotating load without damaging the ASD or the motor.
- (5) The ability to keep a log of a minimum of four previous fault conditions, indicating the fault type and time of occurrence in descriptive text.
- (6) The ability to sustain 110 percent rated current for 60 seconds.
- (7) The ability to shutdown safely or protect against and record the following fault conditions:
  - (a) Over current (and an indication if the over current was during acceleration, deceleration, or running).
  - (b) Over current internal to the drive.
  - (c) Motor overload at start-up.
  - (d) Over voltage from utility power.
  - (e) Motor running overload.
  - (f) Over voltage during deceleration.
  - (g) ASD over heat.
  - (h) Load and ground fault.
  - (h) Abnormal parameters or data in ASD EEPROM.

## 2.2 ENCLOSURES

Provide equipment enclosures conforming to NEMA 250, NEMA ICS 7, and NEMA ICS 6, with a heater if located outdoors. An HMCP device shall provide the disconnecting means. The operating handle shall protrude through the door, but the disconnect shall not be mounted on the door. The handle shall indicate ON, OFF, and tripped conditions. The handle shall have provisions to accommodate a minimum of three padlocks in the OFF position. Interlocks shall prevent unauthorized opening or closing of the ASD door with the disconnect handle in the ON position. The door handle interlock should have provisions to be defeated by qualified

maintenance personnel.

### 2.3 WIRES AND CABLES

All wires and cables must conform to NEMA 250, NEMA ICS 7, NFPA 70.

### 2.4 NAMEPLATES

Nameplates external to NEMA enclosures must conform with the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide manufacturer's standard, permanent nameplates for internal areas of enclosures.

### 2.5 SOURCE QUALITY CONTROL

#### 2.5.1 ASD Test Plan

To ensure quality, each ASD must be subject to a series of in-plant quality control inspections before approval for shipment from the manufacturer's facilities. Provide test plans.

#### 2.5.2 ASD Test Report

To ensure quality, each ASD must be subject to a series of in-plant quality control inspections before approval for shipment from the manufacturer's facilities. Provide test reports.

## PART 3 EXECUTION

### 3.1 INSTALLATION

Per NEMA ICS 3.1, install equipment in accordance with the approved manufacturer's printed installation drawings, instructions, wiring diagrams, and as indicated on project drawings and the approved shop drawings. A field representative of the drive manufacturer must supervise the installation of all equipment, and wiring.

### 3.2 GROUNDING

Per NEMA ICS 7.2, ASD must be solidly grounded to the main distribution.

### 3.3 FIELD QUALITY CONTROL

Specified products must be tested as a system for conformance to specification requirements prior to scheduling the acceptance tests. Conduct performance verification tests in the presence of Government representative, observing and documenting complete compliance of the system to the specifications. Submit a signed copy of the test results, certifying proper system operation before scheduling tests.

#### 3.3.1 ASD Test

A proposed test plan must be submitted to the contracting officer at least 28 calendar days prior to proposed testing for approval. The tests must conform to NEMA ICS 1, NEMA ICS 7, and all manufacturer's safety regulations. The Government reserves the right to witness all tests and review any documentation. Inform the Government at least 14 working days prior to the dates of testing. Perform the ASD test with the assistance of a factory-authorized service representative.

### 3.3.2 Performance Verification Tests

"Performance Verification Test" plan must provide the step by step procedure required to establish formal verification of the performance of the ASD. Compliance with the specification requirements must be verified by inspections, review of critical data, demonstrations, and tests. The Government reserves the right to witness all tests, review data, and request other such additional inspections and repeat tests as necessary to ensure that the system and provided services conform to the stated requirements. Inform the Government 14 calendar days prior to the date the test is to be conducted.

### 3.3.3 Endurance Test

Immediately upon completion of the performance verification test, the endurance test must commence. The system must be operated at varying rates for not less than 192 consecutive hours, at an average effectiveness level of 0.9998, to demonstrate proper functioning of the complete PCS. Continue the test on a day-to-day basis until performance standard is met. The contractor is not allowed in the building during the endurance test. The system must respond as designed.

## 3.4 DEMONSTRATION

### 3.4.1 Training

Coordinate training requirements with the Contracting Officer. Provide video tapes, if available, of all training provided to the Government for subsequent use in training new personnel. Provide all training aids, texts, and expendable support material for a self-sufficient presentation shall be provided, the amount of which to be determined by the contracting officer.

#### 3.4.1.1 Instructions to Government Personnel

Provide the services of competent instructors with minimum two-year field experience with the operation and maintenance of similar ASDs who will give full instruction to designated personnel in operation, maintenance, calibration, configuration, and programming of the complete control system. Orient the training specifically to the system installed. Instructors must be thoroughly familiar with the subject matter they are to teach. The number of training days of instruction furnished must be as specified. A training day is defined as eight hours of instruction, including two 15-minute breaks and excluding lunch time; Monday through Friday. Provide a training manual for each student at each training phase which describes in detail the material included in each training program. Provide one additional copy for archiving. Provide equipment and materials required for classroom training. Provide a list of additional related courses, and offers, noting any courses recommended. List each training course individually by name, including duration, approximate cost per person, and location of course. Unused copies of training manuals must be turned over to the Government at the end of last training session.

#### 3.4.1.2 Operating Personnel Training Program

Provide one 2-hour training session at the site at a time and place mutually agreeable between the Contractor and the Government. Provide session to train 4 operation personnel in the functional operations of the system and the procedures that personnel will follow in system operation.

This training shall include:

- a. System overview
- b. General theory of operation
- c. System operation
- d. Alarm formats
- e. Failure recovery procedures
- f. Troubleshooting

#### 3.4.1.3 Engineering/Maintenance Personnel Training

Accomplish the training program as specified. Training must be conducted on site at a location designated by the Government. Provide a one-day training session to train four engineering personnel in the functional operations of the system. This training must include:

- a. System overview
- b. General theory of operation
- c. System operation
- d. System configuration
- e. Alarm formats
- f. Failure recovery procedures
- g. Troubleshooting and repair
- h. Maintenance and calibration
- i. System programming and configuration

-- End of Section --



SECTION 26 35 34

ELECTROMAGNETIC FILTERS

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 B545 (2012) Standard Specification for Electrodeposited Coatings of Tin

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 299 (2006; R 2012) Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures

IEEE C62.11 (2020) Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1kV)

IEEE C62.33 (2016) Test Methods and Performance Values for Metal-Oxide Varistor Surge Protective Components

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

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

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

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-220 (2009; Rev C; Notice 1 2014; Notice 2 2019) Method of Insertion Loss Measurement

UNDERWRITERS LABORATORIES (UL)

UL 486A-486B	(2018; Reprint Jul 2023) UL Standard for Safety Wire Connectors
UL 1283	(2017) UL Standard for Safety Electromagnetic Interference Filters
UL 1449	(2021; Reprint Dec 2022) UL Standard for Safety Surge Protective Devices

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 Notebook, 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

Filter Assemblies; G

SD-06 Test Reports

Factory Tests  
Impulse Sparkover Voltage  
ESA Extinguishing Test  
ESA Extreme Duty Discharge Test

SD-10 Operation and Maintenance Data

Operating and Maintenance Manuals; G  
Service Organization; G

SD-11 Closeout Submittals

Installation

1.3 DELIVERY, STORAGE, AND HANDLING

Protect equipment delivered and stored from excessive humidity and temperature variation, dirt, and other contaminants.

PART 2 PRODUCTS

2.1 SYSTEM REQUIREMENTS

2.1.1 Factory Tests

Perform factory tests as specified. The Contracting Officer reserves the right to witness the specified factory tests. Notify the Contracting Officer at least 30 days before factory tests are scheduled to be performed. Test data shall include a detailed description of the test instrumentation and equipment, including calibration dates, a detailed description of the test procedure, and the recorded test data.

## 2.2 MATERIALS AND EQUIPMENT

### 2.2.1 Standard Products

Provide materials and equipment which are the standard products of a manufacturer regularly engaged in the manufacture of such products and essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening. Support equipment by a service organization that is, in the opinion of the Contracting Officer, reasonably convenient to the site.

### 2.2.2 Nameplates

Each major item of equipment shall 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.

### 2.2.3 Testability

Equipment shall be designed and built to facilitate testing and maintenance.

## 2.3 ELECTROMAGNETIC FILTERS

Filters and ESAs shall be enclosed in metallic cases which shall protect the filter elements from moisture and mechanical damage. All external bonding or grounding surfaces shall be free from insulating protective finishes. All exposed metallic surfaces shall be suitably protected against corrosion by plating, lead-alloy coating, or other means. The finish shall provide good electrical contact when used on a terminal or as a conductor, shall have uniform texture and appearance, shall be adherent, and shall be free from blisters, pinholes and other defects. The filter and ESA assemblies shall also meet the requirements of UL 1283. Insertion loss in the stop band between the load side of the filter and the power supply side shall be not less than the attenuation specified. Each filter unit shall be capable of being mounted individually and shall include one filter for each phase conductor of the power line and the neutral conductor. The signal filters shall include one filter for each conductor.

### 2.3.1 Enclosure

Filter units shall be mounted in an EM modified NEMA Type 1 enclosure in accordance with NEMA ICS 6 and meet the requirements of UL 1283. Enclosures shall be made of corrosion resistant steel of 14 gauge minimum thickness with welded seams and galvanized bulkhead cover plates. The enclosure nonconductive surfaces shall be finished with a corrosion-inhibiting primer and two coats of baked or finish enamel. The input compartment shall house the individual line filters and the input terminals of the filters and mounting for the surge arrestor. Live parts shall be spaced in accordance with NFPA 70. Filter leads shall be copper. Filter enclosures shall be shielding effectiveness tested in accordance with IEEE 299 and Table I of this specification.

#### 2.3.1.1 Filter Unit Mounting

Each filter unit shall be mounted individually in an enclosure containing one filter for each penetrating conductor. One end of the individual filter case shall be attached to the rf barrier plate between the two compartments to provide a rf tight seal between the rf barrier plate and



the filter case. The terminals of the filters shall project through openings in the rf barrier plate into the inner terminal compartment. The case of each filter shall be attached to both the enclosure and to the barrier plate to prevent undue stress being applied to the rf seal between the filter case and the rf barrier plate. Individual filters shall be removable from the enclosure. Like filters shall be interchangeable.

#### 2.3.1.2 Conduit Connections to Enclosures

The load terminal and input compartments shall have no knockouts, and each compartment shall have weldable threaded conduit hubs. The hubs shall be circumferentially EM welded in place and shall be sized and located as required for the conduits indicated.

#### 2.3.1.3 Access Openings and Cover Plates

Enclosures shall have separate clear front access cover plates on terminal and power input compartments. Access cover plates shall be hinged with EM gaskets and 3 inch maximum bolt spacing. The design shall include thick cover plates and folded enclosure edges to prevent enclosure deformation, bolt spacers to prevent uneven gasket compression, and gasket mounting to facilitate replacement. All gasket contact areas shall be tin-plated using the electrodeposited type I method in accordance with ASTM B545. Nuts and bolts shall be permanently fastened to the enclosure by welding or captive attachments.

#### 2.3.1.4 Operating Temperature

The filter and ESA assembly shall be rated for continuous operation, with filters at rated voltage and full-load currents, in ambient temperatures from minus 55 to plus 65 degrees C (measured outside the EM filter enclosure). Filter components shall be suitable for continuous full load operation at a temperature from minus 55 to plus 85 degrees C.

#### 2.3.1.5 Short Circuit Withstand

Filters shall be labeled and built to have standard short circuit withstand ratings in accordance with UL 1283. The minimum ratings shall be as follows:

FILTER RATED CURRENT, RMS AMPERE	SHORT CIRCUIT FULL LOAD AMPERES SYMMETRICAL
0-100	10,000
101-400	14,000
401-800	42,000

#### 2.3.1.6 Filter Connections

Individual filters shall have prewired standoffs and solderless lugs. The lugs shall be of the hexagonal head bolt or screw type and shall conform to UL 486A-486B. Live parts shall be spaced in accordance with NFPA 70.

### 2.3.2 Internal Encapsulated Filters (Filter Units)

#### 2.3.2.1 Filter Construction

Individual filters shall be heavy-duty type sealed in a steel case. After the filter is filled with an impregnating or encapsulating compound, the seams shall be welded. When a solid potting compound is used to fill the filter, the filters may be mechanically secured and sealed with solder. Hermetically sealed impregnated capacitors shall be used, or the complete filter assembly shall be vacuum impregnated. Individual filter cases shall be fabricated of not less than 14 gauge thick steel and finished with a corrosion-resistant plating, or one coat of corrosion-resistant primer and two coats of finish enamel. The filter shall be filled with an impregnating or potting compound that is chemically inactive with respect to the filter unit and case. The compound, either in the state of original application or as a result of having aged, shall have no adverse effect on the performance of the filter. The same material shall be used for impregnating as is used for filling. Filter terminals shall be copper that can withstand the pull requirements specified and measured in accordance with paragraph ELECTROMAGNETIC FILTERS.

#### 2.3.2.2 Ratings

Filters shall be provided in the current, voltage, and frequency ratings indicated on the drawings.

#### 2.3.2.3 Voltage Drop

Voltage drop through the filter at operation frequency shall not exceed 2 percent of the rated line voltage when the filter is fully loaded with a resistive load (unity power factor). Voltage drop measurements shall be in accordance with paragraph Voltage Drop Measurements.

#### 2.3.2.4 Input Elements

Filters shall be provided with inductive inputs. If inductive input is used an ESA is required to protect the filter. The inductor shall ensure firing potential for the preceding ESA and shall limit the current through the filter capacitor. The input inductor shall be designed to withstand at least a 10,000-volt transient.

#### 2.3.2.5 Drainage of Stored Charge

Filters shall be provided with bleeder resistors to drain the stored charge from the capacitors when power is shut off. Drainage of stored charge shall be in accordance with NFPA 70.

#### 2.3.2.6 Insertion Loss

Insertion loss shall meet or exceed the levels complying with EM shielding effectiveness attenuation requirements herein when measured in accordance with MIL-STD-220. Insertion loss measurements shall be performed in accordance with MIL-STD-220 and the paragraph ELECTROMAGNETIC FILTERS.

#### 2.3.2.7 Operating Temperature Range

Individual filters mounted in the filter enclosure operating at full load amperage and rated voltage shall not exceed plus 185 degrees F based on an ambient temperature of 150 degrees F outside the filter enclosure.

Continuous operation from minus 67 to plus 185 degrees F shall be demonstrated according to paragraph "Filter Life Test (at Elevated Ambient Temperature)". Filters shall also withstand temperature cycling as specified in paragraph ELECTROMAGNETIC FILTERS. The filter shall remain at rated voltage and full-load current until temperature equilibrium is reached or 24 hours, whichever is greater.

#### 2.3.2.8 Current Overload Capability

Filters shall be capable of operating at 140 percent of rated current for 15 minutes, 200 percent of rated current for 1 minute, and 500 percent of rated current for 1 second when tested in accordance with paragraph Overload Test.

#### 2.3.2.9 Reactive Shunt Current

The reactive shunt current drawn by the filter operating at rated voltage shall not exceed 30 percent of the rated full-load current when measured in accordance with paragraph Reactive Shunt Current Measurements.

#### 2.3.2.10 Dielectric Withstand Voltage

Filters shall be provided which conform to the minimum values of dielectric withstanding voltage. Filter dielectric withstand voltage test shall be in accordance with paragraph "Dielectric Withstand Voltage Test". In addition, each filter shall be capable of withstanding a 20-kV or 4-kA peak transient pulse of approximately 20 ns pulse width at full operating voltage, without damage.

#### 2.3.2.11 Insulation Resistance

The insulation resistance between each filter terminal and ground shall be greater than 1 megohm when tested in accordance with paragraph Insulation Resistance Test.

#### 2.3.2.12 Parallel Filters (Current Sharing)

Where two or more individual filters are electrically tied in parallel to form a larger filter, they shall equally share the current. Equally sharing is defined to be within 5 percent of the average current. The tests shall be in accordance with paragraph ELECTROMAGNETIC FILTERS.

#### 2.3.2.13 Harmonic Distortion

Harmonics generated by the insertion of a filter shall not increase line voltage distortion more than 2.5 percent when measured with a unity power factor in accordance with the paragraph ELECTROMAGNETIC FILTERS.

#### 2.3.3 Marking of Filter Units

Each filter case shall be marked with HCI tags and with the rated current, rated voltage, manufacturer's name, type of impregnating or potting compound, operating frequency, and model number. In addition, individual filter cases, the filter enclosures, and supply and load panelboards of filtered circuits shall be marked by the manufacturer with the following: "WARNING: Before working on filters, terminals shall be temporarily grounded to ensure discharge of capacitors. Nameplates and warning labels shall be securely attached.

#### 2.3.4 Minimum Life

Filter assemblies shall be designed for a minimum service life of 15 years. Submit filter schedule including voltage, amperage, enclosure type (low, high, band pass), location, cut-off frequency, band pass frequencies, and electrical surge arresters (ESA). Submit data and/or calculations for design of EM door including schedule of EM penetrations.

#### 2.3.5 Power and Signal Line Factory Testing

Factory test report data shall be submitted for each filter configuration, voltage, and amperage which shall show the ability of filters to meet the specified requirements. Filter test reports shall be based on prior tests of the same filter assembly design and components. Test data reports shall be submitted in accordance with paragraph SUBMITTALS. Test data shall include the following:

- a. Voltage Drop Measurements.
- b. Insertion Loss Measurements.
- c. Filter Life Test.
- d. Thermal Shock Test.
- e. Overload Test.
- f. Reactive Shunt Current Measurements.
- g. Dielectric Withstand Voltage.
- h. Insulation Resistance Test.
- i. Current Sharing.
- j. Harmonic Distortion.
- k. Terminals.

##### 2.3.5.1 Voltage Drop Measurements

The voltage drop measurements on both ac and dc filters shall be performed with the components mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method that will be used for mounting in the enclosure. For ac rated filters, measurements shall be made by using expanded scale-type meters. For dc rated filters, measurements shall be made by using a dc meter when the filter is carrying rated current and rated voltage.

##### 2.3.5.2 Insertion Loss Measurements

Insertion loss measurements for power filters shall have the following modifications. The filters shall be installed in the filter/ESA assembly enclosure. The load current power supply shall operate at the rated voltage of the filters and shall be capable of providing any current from no-load through rated full-load current. The rf signal generator shall be a swept continuous wave (cw) source. The buffer networks shall be modified to permit valid measurements over the entire frequency band on which insertion loss requirements are specified (14 kHz-1 Ghz). The

receiver or network analyzer shall be capable of operating over the entire frequency band on which insertion loss requirements are specified (14 kHz-1 GHz). Sensitivity shall be adequate to provide a measurement dynamic range at least 10 dB greater than the insertion loss requirement. The load impedance shall be resistive and shall be capable of dissipating the rated full-load filter current. Insertion loss measurements shall be made at 20 percent, 50 percent, and 100 percent of the filter full-load operating current. Insertion loss measurements for communication/signal line filters shall be performed the same as for power filters except that the insertion loss measurements are required at a load impedance equal to the image impedance of the filter. No load insertion loss measurements shall be performed over the frequencies defined in the EM shielding effectiveness attenuation requirements for both power and communication filters. Testing shall be load to source for TEMPEST.

#### 2.3.5.3 Filter Life at High Ambient Temperature

This test is conducted for the purpose of determining the effects on electrical and mechanical characteristics of a filter, resulting from exposure of the filter to a high ambient temperature for a specified length of time, while the filter is performing its operational function. Surge current, total resistance, dielectric strength, insulation resistance, and capacitance are types of measurements that would show the deleterious effects due to exposure to elevated ambient temperatures. A suitable test chamber shall be used which will maintain the temperature at the required test temperature and tolerance. Temperature measurements shall be made within a specified number of unobstructed inches from any one filter or group of like filters under test. This test shall be made in still air. Specimens shall be mounted by their normal mounting means. When groups of filters are to be tested simultaneously, the mounting distance between filters shall be as specified for the individual groups otherwise the mounting distance shall be sufficient to minimize the temperature on one filter affecting the temperature of another. Filters fabricated of different materials shall not be tested simultaneously. The test temperature shall be 184 + 34 degrees F. The length of the test shall be for 5,000 hours. Specified measurements shall be made prior to, during, or after exposure.

#### 2.3.5.4 Thermal Shock Test

This test is conducted for the purpose of determining the resistance of a filter to exposures at extremes of high and low temperatures, and to the shock of alternate exposures to these extremes. Suitable temperature controlled systems shall be used to meet the temperature requirements and test conditions. Environmental chambers shall be used to meet test requirements and to reach specified temperature conditions. Filters shall be placed so that there is no obstruction to the flow of air across and around the filter. The filter shall be subjected to the specified test condition. The first five cycles shall be run continuously. After five cycles, the test may be interrupted after the completion of any full cycle, and the filter allowed to return to room ambient temperature before testing is resumed. One cycle consists of steps 1 through 4 of the applicable test condition for dual environmental test chambers (one low temperature and one high temperature test chamber) and steps 1 and 3 for single compartment test chambers where both high and low temperatures are achieved without moving the filter. The test conditions are as follows:

1. -55 deg C. 0 deg and -3 deg
2. 25 deg C. +10 deg and -5 deg

3. 85 deg C. + 3 deg and -0 deg
4. 25 deg C. +10 deg and -5 deg

The effective total transfer time from the specified low temperature to the specified high temperature shall not exceed 5 minutes. The exposure time in air at the extreme temperatures is a function of the weight of the filter. The minimum exposure time per the weight of the filter shall be as follows:

1 oz. and below	15 minutes
Above 1 oz. to 4.8 oz.	30 minutes
Above 4.8 oz. to 3 lb.	1 hour
Above 3 lb. to 30 lb.	2 hours
Above 30 lb. to 300 lb.	4 hours
Above 300 lb.	8 hours

Specified measurements shall be made prior to the first cycle and upon completion of the final cycle, except that failures shall be based on measurements made after the specimen has stabilized at room temperature following the final cycle.

#### 2.3.5.5 Overload Test

Filters shall be mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method that will be used for mounting in the enclosure. A specified current shall then be applied for a specified period of time. After the filter has returned to room temperature, the insulation resistance and voltage drop shall be measured. The insulation resistance shall be measured using the method in paragraph ELECTROMAGNETIC FILTERS. AC voltage drop measurements shall be made by using expanded scale-type meters which will enable voltage differences of less than 1 volt to be read. DC voltage drop measurements shall be made by using a dc reading meter when the filter is carrying rated current and rated voltage. The insulation resistance and the voltage drop will be measured after each separate overload test. Filters will also be visually examined for evidence of physical damage after each test.

#### 2.3.5.6 Reactive Shunt Current Measurements

The reactive shunt current measurements shall be performed with the filters mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method that will be used for mounting in the enclosure. The filter shall be terminated in the inner compartment in an open circuit. Rated ac voltage shall be applied between the filter outer compartment terminal and the enclosure or metal plate. The ac current into the outer compartment terminal shall be monitored. The measured current is equal to the filter reactive shunt current.

### 2.3.5.7 Dielectric Withstand Voltage Test

The dielectric withstanding voltage test (also called high-potential, over potential, .voltage breakdown, or dielectric-strength test) consists of the application of a voltage higher than rated voltage for a specific time between mutually insulated portions of a filter or between insulated portions and ground. Repeated application of the test voltage on the same filter is not recommended as even an overpotential less than the breakdown voltage may injure the insulation. When subsequent application of the test potential is specified in the test routine, succeeding tests shall be made at reduced potential. When an alternating potential (ac) is used, the test voltage shall be 60 Hz. and shall approximate a true sine wave in form. All ac potentials shall be expressed as root-mean-square values. The KVA rating and impedance of the source shall permit operation at all testing loads without serious distortion of the waveform and without serious change in voltage for any setting. When a direct potential (dc) is used, the ripple content shall not exceed 5 percent rms of the test potential. A voltmeter shall be used to measure the applied voltage to an accuracy of 5 percent. When a transformer is used as a high-voltage source of ac, a voltmeter shall be connected across the primary side or across a tertiary winding provided that the actual voltage across the filter will be within the allowable tolerance under any normal load condition. Unless otherwise specified, the test voltage shall be dc and shall be as follows:

DC rated only	2.5 times rated voltage
For filters with ac and dc ratings	2.5 times rated dc voltage
AC rated only	4.2 times rated rms voltage

The duration of the dc test voltages shall be 5 seconds minimum, 1 minute maximum, after the filter has reached thermal stability at maximum operating temperature produced by passage of rated current. The test voltage shall be applied between the case (ground) and all live (not grounded) terminals of the same circuit connected together. The test voltage shall be raised from zero to the specified value as uniformly as possible, at a rate of approximately 500 volts (rms or dc) per second. Upon completion of the test, the test voltage shall be gradually reduced to avoid voltage surges. The changing current shall be 50 mA maximum. During the dielectric withstanding voltage test, the fault indicator shall be monitored for evidence of disruptive discharge and leakage current. The sensitivity of the breakdown test equipment shall be sufficient to indicate breakdown when at least 0.5 mA of leakage current flows through the filter under test. The test shall be performed with the components mounted in the filter/ESA assembly enclosure. Filters for ac circuits shall be tested with an ac source while filters for dc circuits shall be tested with a dc source. After the test the filter shall be examined and measurements shall be performed to include insulation resistance measurements to determine the effect of the dielectric withstanding voltage test on specific operating characteristics.

### 2.3.5.8 Insulation Resistance Test

This is a test to measure the resistance offered by the insulating members of a filter to an impressed direct voltage tending to produce a leakage current through or on the surface of these filters. Insulation-resistance

measurements shall be made on an apparatus suitable for the characteristics of the filter to be measured such as a megohm bridge, megohm-meter, insulation-resistance test set, or other suitable apparatus. The test shall be performed with the components mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method that will be used for mounting in the enclosure. The bleeder resistor shall be disconnected. The direct potential applied to the specimen shall be the largest test condition voltage (100, 500, or 1,000 volts +10 percent) that does not exceed the rated peak ac voltage or the rated dc voltage. A separate dc power supply may be used to charge the filters to the test voltage. The measurement error at the insulation-resistance value required shall not exceed 10 percent. Proper guarding techniques shall be used to prevent erroneous readings due to leakage along undesired paths. Insulation-resistance measurements shall be made between the mutually insulated points or between insulated points and ground. The insulation resistance value shall be read with a megohmmeter and recorded after the reading has stabilized. When more than one measurement is specified, subsequent measurements of insulation resistance shall be made using the same polarity as the initial measurements.

#### 2.3.5.9 Current Sharing

Testing shall be performed with the filters mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method that will be used for mounting in the enclosure. The filter inner compartment terminals shall be loaded with a resistor equal in value to the rated operating voltage divided by the sum of the current ratings of the devices in parallel. The resistor shall be capable of dissipating the total current. Rated operating voltage shall be applied at the filter outer compartment terminals. The current into each filter outer compartment terminal shall be monitored.

#### 2.3.5.10 Harmonic Distortion Test

Harmonic distortion measurements shall be made using a spectrum analyzer having a dynamic range of 70 dB and a frequency range from 10 kHz to 1.7 GHz . Total harmonic distortion shall be measured at the input and output terminals of the filter when operating at 25, 50, and 100 percent of rated full-load current.

#### 2.3.5.11 Terminals Pull Test

The purpose of this test is to determine whether the design of the filter terminals can withstand the mechanical stresses to which they will be subjected during installation or disassembly in equipment. Testing shall be performed with the components mounted in the filter/ESA assembly enclosure or mounted on a plate by the same holding method that will be used for mounting in the enclosure. The force applied to the terminal shall be 20 pounds. The point of application of the force and the force applied shall be in the direction of the axes of the terminations. The force shall be applied gradually to the terminal and then maintained for a period of 5 to 10 seconds. The terminals shall be checked before and after the pull test for poor workmanship, faulty designs, inadequate methods of attaching of the terminals to the body of the part, broken seals, cracking of the materials surrounding the terminals, and the changes in electrical characteristics such as shorted or interrupted circuits. Measurements are to be made before and after the test.



## 2.4 ELECTRICAL SURGE ARRESTERS (ESA)

### 2.4.1 Power and Signal Line ESA

#### 2.4.1.1 ESA General

ESAs shall be metal oxide varistors (MOVs) or spark gaps. When a spark gap is specified, the ESA shall be enclosed within a metal case. Discharges shall be contained within the case; no external corona or arcing will be permitted. ESAs shall be factory installed with minimum lead lengths within the outer compartment. For all power filter/ESA assemblies, the ESAs shall be installed a minimum of 3 inch apart, with terminals at least 3 inch from a grounded surface. For telephone filter/ESA assemblies, the ESAs shall have a minimum clearance spacing of 1 inch, and terminals shall be at least 3 inch from a grounded surface. Each phase, neutral and telephone circuit conductor shall be connected through an ESA to the ground bus. The ESA shall be installed in the power input compartment of the filter. ESA units within the filter/ESA assembly shall be individually replaceable. Like ESAs shall be interchangeable. ESA terminals shall withstand the 20 lb pull test. Live parts shall be spaced in accordance with NFPA 70. ESA leads shall be copper. Individual ESAs shall be marked with HCI tags and shall be marked with the manufacturer's name or trademark and part number. The ESA shall meet the requirements of IEEE C62.11, IEEE C62.41.1, IEEE C62.41.2, and UL 1449.

#### 2.4.1.2 Wiring

The ESAs shall be located so that leads of minimum length connect the ESA ground terminal to the enclosure. The total lead length connecting the ESA to the filter and the ESA ground terminal to the enclosure shall be less than 12 inch. Power line ESA wiring shall be No. 4 AWG minimum. Communication/signal line ESA wiring shall be of the same or heavier gauge than the communication/signal line conductor.

#### 2.4.1.3 Voltage Characteristics

Measurements of (MOV) voltage at 1 mA dc current and spark gap dc breakdown voltage shall be made in accordance with the following procedure. Testing shall be performed with the ESAs mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. A variable dc power supply shall be connected between the ESA terminal and the enclosure (or plate). The applied dc voltage shall be increased at a rate not to exceed 10 percent of the rated firing voltage per second. The (MOV) voltage at 1 mA dc current is the power supply output voltage, when the output current is 1 milliamperere. The spark gap dc breakdown voltage is the applied voltage just prior to breakdown (indicated by a rapid decrease in the voltage across the device). The power supply shall be de-energize immediately after the value has been recorded. MOV direct current breakdown voltage at 1 milliamperere dc current shall be at least 1,000 volts and less than 1,500 volts. MOV testing shall be in accordance with IEEE C62.33. Spark gap direct current breakdown (sparkover) voltage shall be at least 1,000 volts and less than 1,500 volts. Spark gap impulse sparkover voltage of the ESA shall be less than 4,000 volts. This voltage shall be on surges of either polarity having a rate of rise of 1,000 volts/nanosecond. Testing of the ESA impulse sparkover voltage shall be performed with the spark gaps mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. The pulse generator shall be

connected between the spark gap terminal and the enclosure (or plate) with a minimum inductance connection. The pulse generator shall be capable of providing a ramp voltage of 1 kV/ns to a peak voltage which is at least twice the open circuit impulse sparkover voltage. Voltage across the spark gap shall be monitored on an oscilloscope or transient digitizing recorder, capable of at least 1 ns resolution. The peak transient voltage during the pulse is the impulse sparkover voltage. Response time shall be less than 4 nanoseconds. Clamping voltage of the ESA shall be less than 900 volts at a current pulse of 10 kA. ESA clamping voltage measurements shall be performed with the ESAs mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. The pulse generator shall be connected between the ESA terminal and the enclosure (or plate) with a minimum inductance connection. The pulse generator shall be capable of providing a 10 kA current pulse, on an 8- by 20-microsecond waveshape into the ESA. Current through the ESA and voltage across the ESA shall be monitored on oscilloscopes or transient digitizing recorders. The asymptotic voltage during the 10 kA portion of the pulse is the clamping voltage.

#### 2.4.1.4 ESA Extinguishing Characteristics

The ESA shall extinguish and be self-restoring to the normal nonconductive state within one-half cycle at the operating frequency. The ESA extinguishing test shall be performed with the ESA mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. The extinguishing test shall use an ac power source connected between the ESA terminal and ground which shall be at the rated voltage and frequency capable of providing at least 25 amperes into a short-circuit load. A pulse generator capable of providing a short pulse which will fire the ESA shall also be connected across the ESA. Voltage across the ESA shall be monitored on an oscilloscope or transient digitizing recorder. A series of ten pulses shall be injected. Performance of the ESA is satisfactory if the arc extinguishes (indicated by re-occurrence of the sinusoidal waveform) within 8.5 milliseconds after the start of each pulse.

#### 2.4.1.5 ESA Extreme Duty Discharge Current

The ESA shall be rated to survive the extreme duty discharge current of a single 8- x 20-microsecond pulse with a 10 to 90 percent rise time of 8 microseconds and fall time to a value of 36.8 percent of peak in 20 microseconds. The ESA for high voltage power lines (above 600 volts) shall have an extreme duty discharge capability equal to or greater than 70 kA. The ESA for low voltage power lines (below 600 volts) to such things as building interiors, area lighting, and external HVAC equipment shall have an extreme duty discharge capability equal to or greater than 50 kA. The ESAs for control circuits such as interior alarms, indicator lights, door access controllers, HVAC controls, and telephones, shall have an extreme duty discharge capability equal to or greater than 10 kA. The ESA extreme duty discharge test shall be performed with the ESA mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. A pulse generator shall be connected between the ESA terminal and the enclosure (or plate) with a minimum inductance connection. The pulse generator shall be capable of supplying an 8- x 20-microsecond waveshape and a only single pulse is required. Current through the ESA and voltage across the ESA shall be monitored on oscilloscopes or transient digitizing recorders. The ESA shall be visually monitored during the test and after

the pulse inspected for charring, cracks, or other signs of degradation or damage. Test shall be on a prototype only. The dc breakdown voltage test shall be repeated.

#### 2.4.1.6 Minimum Operating Life

The ESA operating life tests shall be performed with the ESA mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. A pulse generator shall be connected between the ESA terminal and the enclosure (or plate) with a minimum inductance connection. The pulse generator shall be capable of supplying repetitive 4 kA current pulses, with a 50 ns x 500 ns waveshape, to the ESA. A series of ten pulses is required. Current through the ESA and voltage across the ESA shall be monitored on oscilloscopes or transient digitizing recorders. The ESA shall be visually monitored during the series of pulses for indications of external breakdown. The ESA shall be able to conduct 2,000 pulses at a peak current of 4 kA and 50 nanoseconds x 500 nanoseconds waveform. Post-test shall include inspection for charring, cracks, or signs of degradation. The dc breakdown voltage test shall be repeated.

#### 2.4.1.7 Operating Temperature

The ESA shall be rated for continuous operation in ambient temperatures from minus 12 to plus 255 degrees F.

#### 2.4.2 ESA Testing

ESA factory test data shall be submitted which shall show the ability to meet the requirements herein, based on prior tests of the same ESA assembly components and design. Testing shall be performed with the ESA mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. The pulse generator shall be connected between the ESA terminal and the enclosure (or plate) with a minimum inductance connection. Current through the ESA and voltage across the ESA shall be monitored on oscilloscopes or transient digitizing recorders. Test data shall include the following:

- a. Breakdown Voltage.
- b. Impulse Sparkover Voltage.
- c. Clamping Voltage.
- d. Extinguishing.
- e. Extreme Duty Discharge.
- f. Surge Life.

### PART 3 EXECUTION

#### 3.1 EXAMINATION

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

### 3.2 INSTALLATION

#### 3.2.1 Manufacturer's Services

Provide the services of a manufacturer's representative who is experienced in the installation, adjustment, and operation of the equipment specified. The representative shall supervise the installation, adjustment, and testing of the equipment.

### 3.3 FIELD TRAINING

Provide a field training course for designated operating and maintenance staff members. Training shall be provided for a total period of 4 hours of normal working time and shall start after the system is functionally complete but prior to the final acceptance test. Field training shall cover all the items contained in the Operating and Maintenance Manuals.

### 3.4 GROUNDING

The contract drawings indicate the extent and general arrangement of the grounding system. See Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

-- End of Section --



SECTION 26 36 00

MANUAL TRANSFER SWITCHES  
05/20, CHG 1: 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.

ASTM INTERNATIONAL (ASTM)

ASTM B117 (2019) Standard Practice for Operating Salt Spray (Fog) Apparatus

ASTM D709 (2017) Standard Specification for Laminated Thermosetting Materials

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS (2021) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250 (2020) Enclosures for Electrical Equipment (1000 Volts Maximum)

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

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

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

NFPA 110 (2022) Standard for Emergency and Standby Power Systems

UNDERWRITERS LABORATORIES (UL)

UL 508 (2018; Reprint Jul 2021) UL Standard for Safety Industrial Control Equipment

UL 1008 (2022) UL Standard for Safety Transfer Switch Equipment

UL 1066

(2022) UL Standard for Safety Low-Voltage  
AC and DC Power Circuit Breakers Used in  
Enclosures

## 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 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

### SD-02 Shop Drawings

Manual Transfer Switch Drawings; G

### SD-03 Product Data

Manual Transfer Switches; GSD-06 Test Reports

Acceptance Checks and Tests; G

Factory Testing; G

Factory Test Reports; G

### SD-07 Certificates

Proof of Listing; G

### SD-10 Operation and Maintenance Data

Operation and Maintenance Manual, Submit in accordance with  
Section 01 78 23 OPERATION AND MAINTENANCE DATA, Data Package 5; G

## 1.3 OPERATION AND MAINTENANCE MANUAL

Assemble and bind manuals in durable, hard-covered, water resistant binders. Assemble and index the manuals per the following table of contents:

- a. Manufacturer's O&M per "SD-10 Operation and Maintenance Data".
- b. Catalog data required by "SD-03 Product Data"
- c. Drawings required by "SD-02 Shop Drawings".

### 1.3.1 Additions to Operation and Maintenance Manuals

In addition to requirements of SD-10 Data Package 5, include the followings on the actual equipment provided:

- a. An outline drawing, front, top, and side views.
- b. Prices for spare parts and supply list.
- c. Date of Purchase.

- d. Corrective maintenance procedures.
- e. Operating manual outlining step-by-step procedures for system startup, operation, and shutdown.
- f. Include simplified wiring and control diagrams in the manual for system as installed.
- g. Provide typical contact voltage drop readings under specified conditions for use during periodic maintenance. Provide instructions for determination of contact integrity.

#### 1.4 QUALITY ASSURANCE

##### 1.4.1 Proof of Listing

Submit proof of listing by UL 1008.

##### 1.4.2 Manual Transfer Switch Drawings

Include the following as a minimum:

- a. An outline drawing, including front, top, and side views.
- b. Provide a nameplate of corrosion-resistant material with not less than 1/8 inch tall characters showing manufacturer's name and equipment ratings. Mount nameplate to front of enclosure and meet the nameplate requirements of NEMA ICS 2.
- c. Provide detail drawings that include manufacturer's name and catalog number, electrical ratings, total system transfer statement, reduced normal supply voltage at which transfer to the alternate supply is initiated, short-circuit current rating, wiring diagram, description of interconnections, testing instructions, acceptable conductor type for terminals, tightening torque for each wire connector, and other required UL 1008 markings.
- d. Submit interface equipment connection diagram showing conduit and wiring between MTS and related equipment. Provide diagrams showing interlocking provisions and cautionary notes, if any.
- e. Drawings are to indicate adequate clearance for operation, maintenance, and replacement of operating equipment devices.

##### 1.4.3 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

##### 1.4.4 Standard Product

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.

#### 1.4.4.1 Alternative Qualifications

Products having less than a 2-year field service record are acceptable if the manufacturer has been regularly engaged in the design and production of manual transfer switches and if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

#### 1.4.4.2 Material and Equipment Manufacturing Date

Products manufactured more than 1 years prior to date of delivery to site are not acceptable.

### 1.5 DELIVERY AND STORAGE

Protect equipment placed in storage from humidity and temperature variations, moisture, water intrusion, dirt, dust, or other contaminants. In harsh environments where temperatures exceed non-operational parameters established within this specification, provide an environmentally controlled equipment storage facility to ensure temperature parameters are within equipment specification. Provide documentation of same to the Government when storage is implemented.

### 1.6 ENVIRONMENTAL CONDITIONS

Provide a MTS that is suitable for prolonged performance under following service conditions:

- a. Operating altitude: Sealevel to 3,300 ft. (Systems applied at higher altitudes are to be derated in accordance with the manufacturer's instructions).
- b. Operating ambient temperature range: 40 to 104 degrees F.
- c. Operating relative humidity: 0 to 90 percent, without condensation.

## PART 2 PRODUCTS

### 2.1 MANUAL TRANSFER SWITCHES

Each manual transfer switch must be rated and marked for total system transfer and have the current and voltage ratings as indicated. Provide a switch operating mechanism that is electrically operated, have quick-make, quick-break, load break contacts, and be mechanically held in both positions. Switches utilizing circuit breakers are not acceptable.

Provide a MTS that is UL listed. MTS must be manufactured and tested in accordance with applicable requirements of NEMA ICS 2, UL 1008 and UL 1066. MTS must conform to NFPA 110. Provide the MTS with the following characteristics:

- a. Voltage: 480 volts ac.
- b. Amperage: 1200 amps ac. Provide a MTS with a continuous load current rating of the switch rating.
- c. Number of Phases: Three.
- d. Number of Wires: Four.
- e. Frequency: 60 Hz.
- f. Poles: Four switched. One of the poles is the neutral.
- g. MTS Withstand Current Rating: MTS must be rated to close on and withstand the available RMS symmetrical short circuit current at the MTS terminals. The MTS must be listed in accordance with UL 1008 for 3 cycle close and withstand ratings. Minimum UL listed close and withstand ratings at 208 VAC 480 VAC must be 25 kA.
- h. Nonwelding Contacts: Provide contacts that are nonwelding at the available fault current rating. Contacts must be suitable for repetitive power transfer switching. Switches rated 800 amps and above must have segmented, blow-on construction for high withstand and close-on capability and be protected by separate arcing contacts.
- i. Phase and Neutral Contacts: Provide contacts with silver alloy composition. Provide neutral contacts with the same continuous current rating as main or phase contacts.
- j. Configuration. Provide an MTS for use in optional standby systems described in NFPA 70.
- k. MTS Configuration. Provide an open transition MTS.
- l. Service Entrance Rated. Provide an integrated circuit breaker and manual transfer switch. Provide a separate deadfront compartment for the circuit breaker on switches 600 amp and larger. Provide label indicating that the MTS is the service disconnect. Provide a circuit breaker that is rated for 100 percent of the switch contact current rating. All components, except as noted herein, are to have a continuous load rating.

## 2.2 ENCLOSURE

Provide an enclosure that meets the following:

- a. Provide MTS and accessories in a free-standing, floor-mounted, ventilated NEMA 250, Type 3R, smooth sheet metal enclosure constructed in accordance with applicable requirements of NEMA ICS 6, UL 508, UL 1066, and UL 1008. Provide door with suitable hinges, locking handle latch, and gasketed jamb. Provide at least No. 14 metal gauge.
- b. Factory wiring within enclosure and field wiring terminating within enclosure must comply with NFPA 70. Provide wire that is permanently

tagged or marked near terminal at each end with wire number shown on approved detail drawing, when wiring is not color coded. Conform terminal block to NEMA ICS 4. Arrange terminals for entrance of external conductors from bottom of enclosure as shown. Main switch terminals, including neutral terminal if used, must be pressure type suitable for termination of external copper conductors shown.

- c. Provide thermostatically controlled heater within enclosure to prevent condensation over temperature range stipulated in paragraph SERVICE CONDITIONS.

#### 2.2.1 Construction

Construct enclosure for ease of removal and replacement of MTS components and control devices from front without disconnection of external power conductors or removal or disassembly of major components.

#### 2.2.2 Cleaning and Painting

Protect both the inside and outside surfaces of an enclosure, including means for fastening against corrosion by enameling, galvanizing, plating, powder coating, or other equivalent means. Protection is not required for metal parts that are inherently resistant to corrosion, bearings, sliding surfaces of hinges, or other parts where such protection is impractical. Provide manufacturer's standard finish material, process, and color that is free from runs, sags, peeling, or other defects. An enclosure marked Type 1, 3R, 4 or 12 is acceptable if there is no visible rust at the conclusion of a salt spray (fog) test using the test method in ASTM B117, employing a 5 percent by weight, salt solution for 24 hours. Type 4X enclosures are acceptable following performance of the above test with an exposure time of 200 hours.

#### 2.2.3 Field Fabricated Nameplates

Nameplate is to comply with ASTM D709. Provide laminated plastic nameplates for each equipment enclosure as specified or as indicated on the drawings. Provide an inscription on each nameplate that identifies the name of the equipment, sources of power, calculated short circuit with date and the location e.g. 'SWB-1 Electrical Room 103'. Provide nameplates that are made of melamine plastic, 0.125 inch thick, white with black center core. Provide the nameplate with a surface that is matte finished and that has square corners.. Accurately align lettering and engrave into the core. Provide nameplates that are at least 1.0 by 2.5 inches with a minimum lettering size of 0.25 inch high normal block style.

### 2.3 FACTORY TESTING

Submit a description of proposed field test procedures, including proposed date and steps describing each test, its duration and expected results, not less than weeks prior to test date. Submit certified factory and field test reports, within 14 days following completion of tests. Provide reports that are certified and dated and that demonstrate that tests were successfully completed prior to shipment of equipment.

#### 2.3.1 Prototype Factory Testing

A prototype of specified MTS is to be factory tested in accordance with UL 1008. In addition, perform factory tests on each MTS as follows:

- a. Insulation resistance test to ensure integrity and continuity of entire system
- b. Main switch contact resistance test.
- c. Visual inspection to verify that each MTS is as specified.
- d. Mechanical test to verify that MTS sections are free of mechanical hindrances.
- e. Electrical tests to verify complete system electrical operation.

### 2.3.2 Factory Test Reports

Provide three certified copies of factory test reports from the manufacturer.

## PART 3 EXECUTION

### 3.1 INSTALLATION

Installation must conform to the requirements of NFPA 70 and manufacturer's recommendation.

### 3.2 FIELD QUALITY CONTROL

Give Contracting Officer 15 days notice of dates and times scheduled for 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. The contractor is responsible for costs associated with conducting tests outside of normal working hours and with incorporating special arrangements and procedures, including temporary power conditions. The contractor provides labor, equipment, apparatus, including test load, and consumables required for the specified tests. Calibration of all measuring devices and indicating devices must be certified. Provide the services of a qualified factory-trained manufacturer's representative to assist the contractor in installation and start-up of the equipment specified under this section. The manufacturer's representative is to provide technical direction and assistance to the contractor in general assembly of the equipment, connections and adjustments, and testing of the assembly components contained herein. Provide a test load that is a cataloged product in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Perform the following field tests in accordance with the manufacturer's recommendations and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS.

#### 3.2.1 Manual Transfer Switch Acceptance Checks and Tests

- a. Visual and Mechanical Inspection
  - (1) Compare equipment nameplate data with specifications and approved shop drawings.
  - (2) Inspect physical and mechanical condition.
  - (3) Confirm correct application of manufacturer's recommended lubricants.

- (4) Verify that manual transfer warnings are attached and visible.
- (5) Verify tightness of all control connections.
- (6) Verify tightness of accessible bolted connections by calibrated torque-wrench method. Thermographic survey is not required.
- (7) Perform manual transfer operation.
- (8) Verify positive mechanical interlocking between normal and alternate sources.

b. Electrical Tests

- (1) Measure contact-resistance. Correct values that exceed 500 microhms and values for 1 pole deviating by more than 50 percent from other poles.
- (2) Perform insulation-resistance on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole for one minute. Perform tests in both source positions.
- (3) Verify settings and operations of control devices.

3.3 TRAINING

Provide 4 hours of training to maintenance personnel on the proper operation, maintenance and adjustment of the manual transfer switch. Coordinate this training with that of the generator equipment.

-- 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" 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 Notebook, 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. 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 14.00 10

CATHODIC PROTECTION SYSTEM (SACRIFICIAL ANODE)  
08/09

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 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 D1248 | (2016) Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable |

NACE INTERNATIONAL (NACE)

- |             |   |
|-------------|---|
| NACE SP0169 | (2013) Control of External Corrosion on Underground or Submerged Metallic 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                          |

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

- |           |   |
|-----------|---|
| 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. 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 6	(2022) UL Standard for Safety Electrical Rigid Metal Conduit-Steel
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

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 Notebook, 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

Drawings; G  
Contractor's Modifications; G

SD-03 Product Data

Equipment; G  
Spare Parts

SD-06 Test Reports

Tests and Measurements; G  
Contractor's Modifications; G

SD-07 Certificates

Cathodic Protection System  
Services of "Corrosion Expert"; G

SD-10 Operation and Maintenance Data

Cathodic Protection System; G  
Training Course; G

1.3 QUALITY ASSURANCE

1.3.1 Services of "Corrosion Expert"

Obtain the services of a "corrosion expert" to supervise, inspect, and test the installation and performance of the cathodic protection system. "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 surfaces.

a. Such a person must be accredited or certified by the National

Association of Corrosion Engineers (NACE) as a NACE Accredited Corrosion Specialist or a NACE certified Cathodic Protection (CP) Specialist or be a registered professional engineer who has certification or licensing that includes education and experience in corrosion control of buried or submerged metallic piping and tank systems, if such certification or licensing includes 5 years experience in corrosion control on underground metallic surfaces of the type under this contract.

- b. The "corrosion expert" shall make at least 3 visits to the project site. The first of these visits shall include obtaining soil resistivity data, acknowledging the type of pipeline coatings to be used and reporting to the Contractor the type of cathodic protection required. Once the submittals are approved and the materials delivered, the "corrosion expert" shall revisit the site to ensure the Contractor understands installation practices and laying out the components. The third visit shall involve testing the installed cathodic protection systems and training applicable personnel on proper maintenance techniques. The "corrosion expert" shall supervise installation and testing of all cathodic protection.
- c. Submit evidence of qualifications of the "corrosion expert" including its name and qualifications certified in writing to the Contracting Officer prior to the start of construction. Certification shall be submitted giving the name of the firm, the number of years of experience, and a list of not less than five (5) of the firm's installations, three (3) or more years old, that have been tested and found satisfactory.

#### 1.3.2 Isolators

Isolators are required to insulate the indicated pipes from any other structure. Isolators shall be provided with lightning protection and a test.

#### 1.3.3 Anode and Bond Wires

A minimum of 5 magnesium anodes with an unpackaged weight of 7 pounds shall be provided uniform distances along the metallic pipe lines. A minimum of 3 test stations shall be used for these anodes. These anodes shall be in addition to anodes for the pipe under concrete slab and casing requirements. For each cathodic system, the metallic components and structures to be protected shall be made electrically continuous. This shall be accomplished 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. Provisions shall be included to return stray current to its source without damaging structures intercepting the stray current. The electrical isolation of underground facilities in accordance with acceptable industry practice shall be included under this section. All tests shall be witnessed by the Contracting Officer.

#### 1.3.4 Surge Protection

Approved zinc grounding cells or sealed weatherproof lightning arrestor devices shall be installed across insulated flanges or fittings installed in underground piping. The arrestor shall be gapless, self-healing, solid state type. Zinc anode composition shall conform to ASTM B418, Type II. Lead wires shall be number 6 AWG copper with high molecular weight



polyethylene (HMWPE) insulation. The zinc grounding cells shall not be prepackaged in backfill. Lightning arrestors or zinc grounding cells are not required for insulated flanges on metallic components used on nonmetallic piping systems.

#### 1.3.5 Nonmetallic Pipe System

In the event pipe other than metallic pipe is approved and used in lieu of metallic pipe, all metallic components of this pipe system shall be protected with cathodic protection. Detailed drawings of cathodic protection for each component shall be submitted to the Contracting Officer for approval within 45 days after date of receipt of notice to proceed, and before commencement of any work.

##### 1.3.5.1 Coatings

Coatings for metallic components shall be as required for metallic fittings. Protective covering (coating and taping) shall be completed and tested on each metallic component (such as valves, hydrants and fillings). This covering shall be as required for underground metallic pipe. Each test shall be witnessed by the Contracting Officer. Coatings shall be selected, applied, and inspected as specified in these specifications. The use of nonmetallic pipe does not change other requirements of the specifications. Any deviations due to the use of nonmetallic pipe shall be submitted for approval.

##### 1.3.5.2 Tracer Wire

When a nonmetallic pipe line is used to extend or add to an existing metallic line, an insulated No. 8 AWG copper wire shall be thermit-welded to the existing metallic line and run the length of the new nonmetallic line. This wire shall be used as a locator tracer wire and to maintain continuity to any future extensions of the pipe line.

##### 1.3.6 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, 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, insulated fittings, test stations, permanent reference cells, and bonding, and any other details required to demonstrate that the system has been coordinated and will function properly as a unit. Locations shall be referenced to two (2) permanent facilities or mark points.

#### 1.4 DELIVERY, STORAGE, AND HANDLING

Storage area for magnesium anodes will be designated by the Contracting Officer. If anodes are not stored in a building, tarps or similar protection should be used to protect anodes from inclement weather. Packaged anodes, damaged as a result of improper handling or being exposed to rain, shall be resacked and the required backfill added.

#### 1.5 EXTRA MATERIALS

After approval of shop drawings, and not later than three (3) months prior

to the date of beneficial occupancy, furnish spare parts data for each different item of material and equipment specified, after approval of detail drawings and not later than six (6) months prior to the date of beneficial occupancy. The data shall include a complete list of parts, special tools, and supplies, with current unit prices and source of supply. One (1) spare anode of each type shall 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.

## PART 2 PRODUCTS

### 2.1 SYSTEM DESCRIPTION

Provide a complete, operating, sacrificial anode cathodic protection system in complete compliance with NFPA 70, with all applicable Federal, State, and local regulations and with the minimum requirements of this contract.

- a. In addition to the minimum requirements of these specifications, construction of gas pipelines and associated cathodic protection systems shall be in compliance with 49 CFR 192 .
- b. The services required include planning, installation, adjusting and testing of a cathodic protection system, using sacrificial anodes for cathodic protection of the Water, Fire Protection, Gas lines, their connectors and lines under the slab or floor foundation. The cathodic protection system shall include anodes, cables, connectors, corrosion protection test stations, and any other equipment required for a complete operating system providing the NACE criteria of protection as specified.
- c. Submit an itemized list of equipment and materials including item number, quantity, and manufacturer of each item, within 30 days after receipt of notice to proceed. The list shall be accompanied by a description of procedures for each type of testing and adjustments, including testing of coating for thickness and holidays. Installation of materials and equipment shall not commence until this submittal is approved. Insulators are required whenever needed to insulate the pipes from any other structure. Any pipe crossing the pipe shall have a test station. The cathodic protection shall be provided on Water, Fire Protection, Gas pipes.
- d. Submit proof that the materials and equipment furnished under this section conform to the specified requirements contained in the referenced standards or publications. The label or listing by the specified agency will be acceptable evidence of such compliance.
- e. Before final acceptance of the cathodic protection system, submit 6 copies of operating manuals outlining the step-by-step procedures required for system startup, operation, adjustment of current flow, and shutdown. The manuals shall include the manufacturer's name, model number, service manual, parts list, and brief description of all equipment and their basic operating features.
- f. Submit 6 copies of maintenance manuals, listing routine maintenance procedures, recommendation for maintenance testing, possible breakdowns and repairs, and troubleshooting guides. The manuals shall include single-line diagrams for the system as installed; instructions

in making pipe-to-reference cell and tank-to-reference cell potential measurements and frequency of monitoring; instructions for dielectric connections, interference and sacrificial anode bonds; instructions shall include precautions to ensure safe conditions during repair of pipe or other metallic systems. The instructions shall be neatly bound between permanent covers and titled "Operating and Maintenance Instructions." These instructions shall be submitted for the Contracting Officer's approval. The instructions shall include the following:

- (1) As-built drawings, to scale, of the entire system, showing the locations of the piping, location of all anodes and test stations, locations of all insulating joints, and structure-to-soil potential test points as measured during the tests required by paragraph TESTS AND MEASUREMENTS. Each test point shall be given a unique alphanumeric identification that is cross referenced to the data sheets.
- (2) Recommendations for maintenance testing, including instructions in making pipe-to-reference cell potential measurements and frequency of testing.
- (3) All maintenance and operating instructions and nameplate data shall be in English.
- (4) Instructions shall include precautions to insure safe conditions during repair of pipe system.

#### 2.1.1.1 Contractor's Modifications

The specified system is based on a complete system with magnesium sacrificial anodes. The Contractor may modify the cathodic protection system after review of the project, site verification, and analysis, if the proposed modifications include the anodes specified and will provide better overall system performance.

- a. Submit six copies of detail drawings showing proposed changes in location, scope of performance indicating any variations from, additions to, or clarifications of contract drawings. Show proposed changes in anode arrangement, anode size and number, anode materials and layout details, conduit size, wire size, mounting details, wiring diagram, method for electrically-isolating each pipe, and any other pertinent information to proper installation and performance of the system. The modifications shall be fully described, shall be approved by the Contracting Officer, and shall meet the following criteria.
- b. The proposed system shall achieve a minimum pipe-to-soil "instant off" potential of minus 850 millivolts with reference to a saturated copper-copper sulfate reference cell on the underground components of the piping or other metallic surface. Take resistivity measurements of the soil in the vicinity of the pipes and ground bed sites. Based upon the measurements taken, the current and voltage shall be required to produce a minimum of minus 850 millivolts "instant off" potential between the structure being tested and the reference cell. This potential shall be obtained over 95 percent of the metallic area. The anode system shall be designed for a life of twenty-five (25) years of continuous operation.
- c. Submit final report regarding Contractor's modifications. The report

shall include pipe-to-soil measurements throughout the affected area, indicating that the modifications improved the overall conditions, and current measurements for anodes. The following special materials and information are required: taping materials and conductors; zinc grounding cell, installation and testing procedures, and equipment; coating material; system design calculations for anode number, life, and parameters to achieve protective potential; backfill shield material and installation details showing waterproofing; bonding and waterproofing details; insulated resistance wire; exothermic weld equipment and material.

#### 2.1.2 Summary of Services Required

The scope of services shall include, but shall not be limited to, the following:

- a. Close-interval potential surveys.
- b. Cathodic Protection Systems.
- c. System testing.
- d. Casing corrosion control.
- e. Interference testing.
- f. Training.
- g. Operating and maintenance manual.
- h. Insulator testing and bonding testing.
- i. Coating and holiday testing to be submitted within 45 days of notice to proceed.

#### 2.1.3 Tests of Components

Perform a minimum of four (4) tests at each metallic component in the piping system. Two (2) measurements shall be made directly over the anodes and the other two (2) tests shall be over the outer edge of the component, but at the farthest point from the anodes. Structure and pipes shall be shown with the cathodic protection equipment. All components of the cathodic protection system shall be shown on drawings, showing their relationship to the protected structure or component. A narrative shall describe how the cathodic protection system will work and provide testing at each component. Components requiring cathodic protection shall include but not be limited to the following:

- a. Pipes under the floor slab or foundations.
- b. PIV.
- c. Shutoff valves.
- d. Metallic pipe extended from aboveground locations.
- e. Each connector or change-of-direction device.
- f. Any metallic pipe component or section.

g. Backflow preventer.

h. Culvert.

#### 2.1.4 Electrical Potential Measurements

All potential tests shall be made at a minimum of 10 foot intervals witnessed by the Contracting Officer. Submittals shall identify test locations on separate drawing, showing all metal to be protected and all cathodic protection equipment. Test points equipment and protected metal shall be easily distinguished and identified.

#### 2.1.5 Achievement of Criteria for Protection

All conductors, unless otherwise shown, shall be routed to or through the test stations. Each system provided shall achieve a minimum pipe-to-soil "instant off" potential of minus 850 millivolt potentials with reference to a saturated copper-copper-sulfate reference cell on all underground components of the piping. Based upon the measurements taken, the current and voltage of the anodes should be adjusted as required to produce a minimum of minus 850 millivolts "instant off" potential between the structure being tested and the reference cell. This potential should be obtained over 95 percent of the metallic area. This must be achieved without the "instant off" potential exceeding 1150 millivolts. Testing will be witnessed by the Contracting Officer. Provide additional anodes if required to achieve the minus 850 millivolts "instant off". Although acceptance criteria of the cathodic protection systems are defined in NACE SP0169, for this project the "instant off" potential of minus 850 millivolts is the only acceptable criteria.

#### 2.1.6 Metallic Components on Nonmetallic Systems and Typical

##### 2.1.6.1 Metallic Components

As a minimum, protect each metallic component with two (2) magnesium 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 1150 millivolts "instant off." As a minimum, the magnesium anode unpackaged weight shall be 9 pounds. The magnesium anodes shall be located on each side of the metallic component and routed through a test station.

##### 2.1.6.2 Fire Hydrants

Fire hydrant pipe components shall have a minimum of two (2) anodes. These magnesium anodes shall have an unpackaged weight of 17 pounds.

##### 2.1.6.3 Pipe Under Concrete Slab

Pipe under concrete slab shall have a minimum of 2 magnesium anodes. These magnesium anodes shall have an unpackaged weight of 9 pounds. Pipe under concrete slab shall have 1 permanent reference electrodes located under the slab. One (1) permanent reference electrode shall be located where the pipe enters the concrete slab. All conductors shall be routed to a test station.

2.1.6.4 Valves

Each valve shall be protected with 2 magnesium anodes. The magnesium anode shall have an unpackaged weight of 9 pounds.

2.1.6.5 Metallic Pipe Component or Section

Each section of metallic pipe shall be protected with 2 magnesium anodes. The magnesium anodes shall have an unpackaged weight of 9 pounds.

2.1.6.6 Connectors or Change-of-Direction Devices

Each change-of-direction device shall be protected with 2 magnesium anodes. The magnesium anode shall have an unpackaged weight of 9 pounds.

2.1.7 Metallic Component Coating

Coatings for metallic components shall be as required for metallic fittings as indicated. This will include fire hydrants, T's, elbows, valves, etc. Coatings shall be selected, applied, and inspected as specified in these specifications. All aboveground pipeline shall be coated as indicated or as approved. The coating shall have a minimum thickness of 7 mil. The pipeline coating shall be in accordance with all applicable Federal, State, and local regulations.

2.2 MAGNESIUM ANODES

Install a minimum of 2 anodes on the Pipe and Tank systems. See Paragraph METALLIC COMPONENTS ON NONMETALLIC SYSTEMS AND TYPICALS for additional anodes under slab.

2.2.1 Anode Composition

Anodes shall be of high-potential magnesium alloy, made of primary magnesium obtained from sea water or brine, and not made from scrap metal. Magnesium anodes shall conform to ASTM B843 and to the following analysis (in percents) otherwise indicated:

Aluminum, max.	0.010
Manganese, max.	0.50 to 1.30
Zinc	0.05
Silicon, max.	0.05
Copper, max.	0.02
Nickel, max.	0.001
Iron, Max.	0.03
Other impurities, max.	0.05 each or 0.3 max. total
Magnesium	Remainder

Furnish spectrographic analysis on samples from each heat or batch of

anodes used on this project.

2.2.2 Dimensions and Weights

Dimensions and weights of anodes shall be approximately as follows:

TYPICAL MAGNESIUM ANODE SIZE (Cross sections may be round, square, or D shaped)			
Nominal Weight (lbs)	Approx. Size (inch)	Nominal Gross Weight (lbs) Packaged in Backfill	Nominal Package Dimensions (inch)
3	3 X 3 X 5	8	5-1/4 X 5-1/4 X 8
5	3 X 3 X 8	13	5-1/4 X 5-1/4 X 11-1/4
9	3 X 3 X 14	27	5-1/4 X 20
12	4 X 4 X 12	32	7-1/2 X 18
17	4 X 4 X 17	45	7-1/2 X 24
32	5 X 5 X 20-1/2	68	8-1/2 X 28
50	7 X 7 X 16	100	10 X 24

2.2.3 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 shall be centered by means of spacers in the backfill material. The backfill material shall have the following composition, unless otherwise indicated:

Material	Approximate Percent by Weight
Gypsum	75
Bentonite	20
Sodium Sulphate	5
Total	100

2.2.4 Zinc Anodes

Zinc anodes shall conform to ASTM B418, Type II.

## 2.2.5 Connecting Wire

### 2.2.5.1 Wire Requirements

Wire shall be No. 10 AWG solid copper wire, not less than 10 feet long, unspliced, complying with NFPA 70, Type RHW-USE insulation. Connecting wires for magnesium anodes shall be factory installed with the place or emergence from the anode in a cavity sealed flush with a dielectric sealing compound.

### 2.2.5.2 Anode Header Cable

Cable for anode header and distribution shall be No. 10 AWG stranded copper wire with type CP high molecular weight polyethylene, 7/64 inch thick insulation, 600-volt rating.

## 2.3 MISCELLANEOUS MATERIALS

### 2.3.1 Electrical Wire

Wire shall be No. 10 AWG stranded copper wire with NFPA 70, Type TW insulation. Polyethylene insulation shall comply with the requirements of ASTM D1248 and shall be of the following types, classes, and grades:

High-molecular weight polyethylene shall be Type I, Class C, Grade E5.

High-density polyethylene shall be Type III, Class C, Grade E3.

#### 2.3.1.1 Wire Splicing

Connecting wire splicing shall be made with copper compression connectors or exothermic welds, following instructions of the manufacturer. Single split-bolt connections shall not be used. Sheaths for encapsulating electrical wire splices to be buried underground shall fit the insulated wires entering the spliced joints and epoxy potting compound shall be as specified below.

#### 2.3.1.2 Test Wires

Test wires shall be AWG No. 12 stranded copper wire with NFPA 70, Type TW or RHW-USE with outer covering or polyethylene insulation.

#### 2.3.1.3 Resistance Wire

Resistance wire shall be AWG No. 16 or No. 22 nickel-chromium wire.

### 2.3.2 Conduit

Rigid galvanized steel conduit and accessories shall conform to UL 6. Non metallic conduit shall conform to NEMA TC 2.

### 2.3.3 Test Boxes and Junctions Boxes

Boxes shall be outdoor type conforming to UL 514A.

### 2.3.4 Joint, Patch, Seal, and Repair Coating

Sealing and dielectric compound shall be a black, rubber based compound that is soft, permanently pliable, tacky, moldable, and unbacked.



Compound shall be applied as recommended by the manufacturer, but not less than 1/2-inch thick. Coating compound shall be cold-applied coal-tar base mastic. Pressure-sensitive vinyl plastic electrical tape shall conform to UL 510.

#### 2.3.5 Backfill Shields

Shields shall consist of approved pipeline wrapping or fiberglass-reinforced, coal-tar impregnated tape, or plastic weld caps, specifically made for the purpose and installed in accordance with the manufacturer's recommendations. When joint bonds are required, due to the use of mechanical joints, the entire joint shall be protected by the use of a kraft paper joint cover. The joint cover shall be filled with poured-in, hot coat-tar enamel.

#### 2.3.6 Epoxy Potting Compound

Compound for encapsulating electrical wire splices to be buried underground shall be a two package system made for the purpose.

#### 2.3.7 Test Stations

Stations shall be of the flush-curb-box type and shall be the standard product of a recognized manufacturer. Test stations shall be complete with an insulated terminal block having the required number of terminals. The test station shall be provided with a lockable over and shall have an embossed legend, "C.P. Test." A minimum of one (1) test station shall be provided each component of the pipe. A minimum of six (6) terminals shall be provided in each test station. A minimum of two (2) leads are required to the metallic pipe from each test station. Other conductors shall be provided for each anode, other foreign pipe, and reference cells as required. Test stations may be constructed of nonmetallic materials. However, if nonmetallic materials are utilized, as a minimum, the materials shall be resistant to damage from ultraviolet radiation, contain good color retention qualities, contain high strength qualities, and be resistant to accidental or vandalistic impacts that might be normally encountered in the environment for which they are to be installed. The test stations shall be listed for the particular application for which they are to be utilized.

#### 2.3.8 Joint and Continuity Bonds

Bonds shall be provided across all joints in the metallic water, gas lines, across any electrically discontinuous connections and all other pipes and structures with other than welded or threaded joints that are included in this cathodic protection system. Unless otherwise specified in the specifications, bonds between structures and across joints in pipe with other than welded or threaded joints shall be No. 8 AWG stranded copper cable with polyethylene insulation. Bonds between structures shall contain sufficient slack for any anticipated movement between structures. Bonds across pipe joints shall contain a minimum of 4 inch of slack to allow for pipe movement and soil stress. Bonds shall be attached by exothermic welding. Exothermic weld areas shall be insulated with coating compound and approved, and witnessed by the Contracting Officer. Continuity bonds shall be installed as necessary to reduce stray current interference. Additional joint bondings shall be accomplished where the necessity is discovered during construction or testing or where the Contracting Officer's representative directs that such bonding be done. Joint bonding shall include all associated excavation and backfilling.

There shall be a minimum of two (2) continuity bonds between each structure and other than welded or threaded joints. Test for electrical continuity across all joints with other than welded or threaded joints and across all metallic portions or components. Provide bonding as required and as specified above until electrical continuity is achieved. Submit bonding test data for approval.

#### 2.3.9 Resistance Bonds

Resistance bonds should be adjusted as outlined in this specification. Alternate methods may be used if they are approved by the Contracting Officer.

#### 2.3.10 Stray Current Measurements

Stray current measurements should be performed at each test station. Stray currents resulting from lightning or overhead alternating current (AC) power transmission systems shall be mitigated in accordance with NACE SP0177.

#### 2.3.11 Electrical Isolation of Structures

As a minimum, isolating flanges or unions shall be provided at the following locations:

- a. Connection of new metallic piping or components to existing piping.
- b. Pressure piping under floor slab to a building.

Isolation shall be provided at metallic connection of all lines to existing system and where connecting to a building. Additionally, isolation shall be provided between water and/or gas line; and foreign pipes that cross the new lines within 10 feet. Isolation fittings, including isolating flanges and couplings, shall be installed aboveground or in a concrete pit.

##### 2.3.11.1 Electrically Isolating Pipe Joints

Electrically isolating pipe joints shall be of a type that is in regular factory production.

##### 2.3.11.2 Electrically Conductive Couplings

Electrically conductive couplings shall be of a type that has a published maximum electrical resistance rating given in the manufacturer's literature. Cradles and seals shall be of a type that is in regular factory production made for the purpose of electrically insulating the carrier pipe from the casing and preventing the incursion of water into the annular space.

##### 2.3.11.3 Insulating Joint Testing

An insulation checker shall be used for insulating joint (flange) electrical testing.

#### 2.3.12 Underground Structure Coating

This coating specification shall take precedence over any other project specification and drawing notes, whether stated or implied, and shall also

apply to the pipeline or tank supplier. No variance in coating quality shall be 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 shall be afforded a good quality factory-applied coating. This includes all carbon steel, cast-iron and ductile-iron pipelines or vessels. Coatings shall be selected, applied, and inspected as specified. If non-metallic pipelines are installed, all metallic fittings on pipe sections shall be coated in accordance with this specification section.

- a. The nominal thickness of the metallic pipe joint or other component coating shall be 40 mils, plus or minus 5 percent.
- b. Pipe and joint coating for factory applied or field repair material shall be applied as recommended by the manufacturer and shall 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.

#### 2.3.12.1 Field Joints

All field joints shall be coated with materials compatible with the pipeline coating compound. The joint coating material shall be applied to an equal thickness as the pipeline coating. Unbonded coatings shall not be used on 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, an inspection of the coating shall be conducted. This inspection shall include electrical holiday detection. Any damaged areas of the coating shall be properly repaired. The Contracting Officer shall be asked to witness inspection of the coating and testing using a holiday detector.

#### 2.3.12.2 Inspection of Pipe Coatings

Any damage to the protective covering during transit and handling shall be repaired before installation. After field coating and wrapping has been applied, the entire pipe shall 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 shall be equipped with a bell, buzzer, or other type of audible signal which sounds when a holiday is detected. All holidays in the protective covering shall be repaired immediately upon detection. Occasional checks of holiday detector potential will be made by the Contracting Officer's representative to determine suitability of the detector. All labor, materials, and equipment necessary for conducting the inspection shall be furnished by the Contractor.

##### 2.3.12.2.1 Protective Covering for Aboveground Piping System

Finish painting shall conform to the applicable paragraph of SECTION: 09 90 00 PAINTS AND COATINGS and as follows:

##### 2.3.12.2.2 Ferrous Surfaces

Shop-primed surfaces shall be touched-up with ferrous metal primer.

Surfaces that have not been shop-primed shall be solvent-cleaned. Surfaces that contain loose rust, loose mil scale, and other foreign substances shall be mechanically-cleaned by power wire-brushing and primed with ferrous metal primer. Primed surface shall be finished with two (2) coats of exterior oil paint and vinyl paint. Coating for each entire piping service shall be an approved pipe line wrapping having a minimum coating resistance of 50,000 Ohms per square foot.

#### 2.3.13 Resistance Wire

Wire shall be No. 16 or No. 22 nickel-chromium wire with TW insulation.

#### 2.3.14 Electrical Connections

Electrical connections shall be done as follows:

- a. Exothermic welds shall use material in strict accordance with the manufacturer's recommendations.
- b. Electrical-shielded arc welds shall be approved for use on steel pipe by shop drawing submittal action.
- c. Brazing shall be as specified in Paragraph: Lead Wire Connections.

#### 2.3.15 Electrical Tape

Pressure-sensitive vinyl plastic electrical tape shall conform to UL 510.

#### 2.3.16 Permanent Reference Electrodes

Permanent reference electrodes shall be Cu-CuSO4 electrodes suitable for direct burial. Electrodes shall be guaranteed by the supplier for 15 years' service in the environment in which they shall be placed. Electrodes shall be installed directly beneath pipe, or metallic component.

#### 2.3.17 Casing

Where a pipeline is installed in a casing under a roadway or railway, the pipeline shall be electrically insulated from the casing, and the annular space sealed and filled with an approved corrosion inhibiting product against incursion of water.

### PART 3 EXECUTION

#### 3.1 CRITERIA OF PROTECTION

Acceptance criteria for determining the adequacy of protection on a buried underground pipe, metallic component shall be in accordance with NACE SP0169 and as specified below.

##### 3.1.1 Iron and Steel

The following method a. shall be used for testing cathodic protection voltages. If more than one method is required, method b. shall be used.

- a. A negative voltage of at least minus 850 millivolts as measured between the underground component and a saturated copper-copper sulphate reference electrode connecting the earth (electrolyte) directly over the underground component. Determination of this

voltage shall be made with the cathodic protection system in operation. Voltage drops shall be considered for valid interpretation of this voltage measurement. A minimum of minus 850 millivolts "instant off" potential between the underground component being tested and the reference cell shall be achieved over 95 percent of the area of the structure. Adequate number of measurements shall be obtained over the entire structure, pipe, tank, or other metallic component to verify and record achievement of minus 850 millivolts "instant off." This potential shall be obtained over 95 percent of the total metallic area without the "instant off" potential exceeding 1200 millivolts.

- b. A minimum polarization voltage shift of 100 millivolts as measured between the underground component and a saturated copper-copper sulphate reference electrode contacting the earth directly over the underground component. This polarization voltage shift shall be determined by interrupting the protective current and measuring the polarization decay. When the protective current is interrupted, an immediate voltage shift will occur. The voltage reading, after the immediate shift, shall be used as the base reading from which to measure polarization decay. Measurements achieving 100 millivolts decay shall be made over 95 percent of the metallic surface being protected.
- c. For any metallic component, a minimum of four (4) measurements shall be made using subparagraph a., above, and achieving the "instant off" potential of minus 850 millivolts. Two (2) measurements shall be made over the anodes and two (2) measurements shall be made at different locations near the component and farthest away from the anode.

### 3.1.2 Aluminum

Aluminum underground component shall not be protected to a potential more negative than minus 1200 millivolts, measured between the underground component and a saturated copper-copper sulphate reference electrode contacting the earth, directly over the metallic component. Resistance, if required, shall 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 shall be a minimum negative polarization shift of 100 millivolts measured between the metallic component and a saturated copper-copper sulphate reference electrode contacting the earth, directly over the metallic component. The polarization voltage shift shall be determined as outlined for iron and steel.

### 3.1.3 Copper Piping

For copper piping, the following criteria shall 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 shall be determined as outlined for iron and steel.

## 3.2 TRENCHING AND BACKFILLING

Perform trenching and backfilling in accordance with Section 31 00 00 EARTHWORK . In the areas of the anode beds, all trees and underbrush shall 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. Alternate

techniques and depths must be approved prior to implementation.

### 3.3 INSTALLATION

#### 3.3.1 Anode Installation

Unless otherwise authorized, installation shall not proceed without the presence of the Contracting Officer. Anodes of the size specified shall 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. Anodes shall 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 shall be designed for a life of 25 years of continuous operation. Anodes shall 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 shall not be used for lowering the anode into the hole. The annular space around the anode shall be backfilled with fine earth in 6 inch layers and each layer shall be hand tamped. Care must be exercised not to strike the anode or connecting wire with the tamper. Approximately 5 gallons of water shall be applied to each filled hole after anode backfilling and tamping has been completed to a point about 6 inch above the anode. After the water has been absorbed by the earth, backfilling shall be completed to the ground surface level.

##### 3.3.1.1 Single Anodes

Single anodes shall be connected through a test station to the pipeline, allowing adequate slack in the connecting wire to compensate for movement during backfill operation.

##### 3.3.1.2 Groups of Anodes

Groups of anodes shall be connected to an anode header cable. The anode header cable shall make contact with the structure to be protected only through a test station. Anode lead connection to the anode header cable shall be made by an approved crimp connector or exothermic weld and splice mold kit with appropriate potting compound.

##### 3.3.1.3 Welding Methods

Connections to ferrous pipe shall be made by exothermic weld methods manufactured for the type of pipe supplied. Electric arc welded connections and other types of welded connections to ferrous pipe and structures shall be approved before use.

#### 3.3.2 Anode Placement - General

Packaged anodes shall be installed completely dry, and shall be lowered into holes by rope sling or by grasping the cloth gather. The anode lead wire shall not be used in lowering the anodes. The hole shall be backfilled with fine soil in 6 inch layers and each layer shall be hand-tamped around the anode. Care must be exercised not to strike the anode or lead wire with the tamper. If immediate testing is to be performed, water shall be added only after backfilling and tamping has been completed to a point 6 inch above the anode. Approximately 2 gallons of water may be poured into the hole. After the water has been absorbed by the soil, backfilling and tamping may be completed to the top of the

hole. Anodes shall be installed as specified or shown. In the event a rock strata is encountered prior to achieving specified augered-hole depth, anodes may be installed horizontally to a depth at least as deep as the bottom of the pipe, with the approval of the Contracting Officer.

### 3.3.3 Underground Pipeline

Anodes shall be installed at a minimum of 8 feet and a maximum of 10 feet from the line to be protected.

### 3.3.4 Installation Details

Details shall conform to the requirements of this specification. Details shown on the drawings are indicative of the general type of material required, and are not intended to restrict selection to material of any particular manufacturer.

### 3.3.5 Lead Wire Connections

#### 3.3.5.1 Underground Pipeline (Metallic)

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 shall be connected to a test station and buried a minimum of 24 inch in depth. The cable shall be No. 10 AWG, stranded copper, polyethylene or RHW-USE insulated cable. The cable shall make contact with the structure only through a test station. Resistance wire shall 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, shall be made with exothermic welding process, and shall be insulated by means of at least three (3) layers of electrical tape; and all lead wire connections shall be installed in a moistureproof splice mold kit and filled with epoxy resin. Lead wire-to-structure connections shall be accomplished by an exothermic welding process. All welds shall be in accordance with the manufacturer's recommendations. A backfill shield filled with a pipeline mastic sealant or material compatible with the coating shall be placed over the weld connection and shall be of such diameter as to cover the exposed metal adequately.

#### 3.3.5.2 Resistance Wire Splices

Resistance wire connections shall be accomplished with silver solder and the solder joints wrapped with a minimum of three (3) layers of pressure-sensitive tape. Lead wire connections shall be installed in a moistureproof splice mold kit and filled with epoxy resin.

### 3.3.6 Location of Test Stations

Test stations shall be curb box mounted. Provide buried insulating 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 insulating joint are not accessible above ground for testing purposes.

### 3.3.7 Underground Pipe Joint Bonds

Underground pipe having other than welded or threaded coupling joints shall be made electrically continuous by means of a bonding connection installed across the joint.

## 3.4 ELECTRICAL ISOLATION OF STRUCTURES

### 3.4.1 Isolation Joints and Fittings

Isolating fittings, including main line isolating flanges and couplings, shall be installed aboveground, or within manholes, wherever possible. Where isolating joints must be covered with soil, they shall be fitted with a paper joint cover specifically manufactured for covering the particular joint, and the space within the cover filled with hot coal-tar enamel. Isolating fittings in lines entering buildings shall be located at least 12 inch above grade of floor level, when possible. Isolating joints shall be provided with grounding cells to protect against over-voltage surges or approved surge protection devices. The cells shall provide a low resistance across isolating joint without excessive loss of cathodic current.

### 3.4.2 Gas Distribution Piping

Electrical isolation shall 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.

## 3.5 TESTS AND MEASUREMENTS

Submit test reports in booklet form tabulating all field tests and measurements performed, upon completion and testing of the installed system and including close interval potential survey, casing and interference tests, final system test verifying protection, insulated joint and bond tests, and holiday coating test. Submit a certified test report showing that the connecting method has passed a 120-day laboratory test without failure at the place of connection, wherein the anode is subjected to maximum recommended current output while immersed in a three percent sodium chloride solution.

### 3.5.1 Baseline Potentials

Each test and measurement will be witnessed by the Contracting Officer. Notify the Contracting Officer a minimum of five (5) working days prior to each test. After backfill of the pipe, the static potential-to-soil of the pipe shall be measured. The locations of these measurements shall be identical to the locations specified for pipe-to-reference electrode potential measurements. The initial measurements shall be recorded.

### 3.5.2 Isolation Testing

Before the anode system is connected to the pipe, an isolation test shall be made at each isolating joint or fitting. This test shall 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 shall be reported to the Contracting Officer.



### 3.5.2.1 Insulation Checker

An insulation checker shall be used for isolating joint (flange) electrical testing. Testing shall conform to the manufacturer's operating instructions. Test shall be witnessed by the Contracting Officer. Location of the fault shall be determined from the instructions, and the joint shall be repaired. If an isolating joint is located inside a vault, the pipe shall be sleeved with insulator when entering and leaving the vault.

### 3.5.2.2 Cathodic Protection Meter

A cathodic protection meter shall be used for isolating joint (flange) electrical testing. Testing shall conform to the manufacturer's operating instructions. This test shall be performed in addition to the insulation checker. The insulation checker verifies that the particular insulation under test is good and the cathodic protection meter verifies that the system is isolated. If the system is shorted, further testing shall be performed to isolate the location of the short.

### 3.5.3 Anode Output

As the anodes or groups of anodes are connected to the pipe, current output shall 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 shall be recorded.

### 3.5.4 Reference Electrode Potential Measurements

Upon completion of the installation and with the entire cathodic protection system in operation, electrode potential measurements shall be made using a copper-copper sulphate 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 shall be identical to the locations used for baseline potentials. The values obtained and the date, time, and locations of measurements shall be recorded. No less than eight (8) measurements shall be made over any length of line or component. Additional measurements shall be made at each distribution service riser, with the reference electrode placed directly over the service line.

### 3.5.5 Location of Measurements

#### 3.5.5.1 Piping or Conduit

For coated piping or conduit, measurements shall be taken from the reference electrode located in contact with the earth, directly over the pipe. Connection to the pipe shall be made at service risers, valves, test leads, or by other means suitable for test purposes. Pipe-to-soil potential measurements shall be made at intervals not exceeding 10 feet. The Contractor may use a continuous pipe-to-soil potential profile in lieu of 5 foot interval pipe-to-soil potential measurements. Additional measurements shall be made at each distribution service riser, with the reference electrode placed directly over the service line adjacent to the

riser. Potentials shall be plotted versus distance to an approved scale. Locations where potentials do not meet or exceed the criteria shall be identified and reported to the Contracting Officer's representative.

#### 3.5.5.2 Tanks

For underground tanks, at least 6 measurements shall be taken from the reference electrode located:

- a. Directly over the center of the tank.
- b. At a point directly over the tank and midway between each pair of anodes.

#### 3.5.5.3 Casing Tests

Before final acceptance of the installation, the electrical separation of carrier pipe from casings shall be tested and any short circuits corrected.

#### 3.5.5.4 Interference Testing

Before final acceptance of the installation, interference tests shall 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 shall be made. Stray current measurements shall be performed at all isolating locations and at locations where the new pipeline crosses foreign metallic pipes; results of stray current measurements shall also be submitted for approval. The method of measurements and locations of measurements shall be submitted for approval. As a minimum, stray current measurements shall be performed at the following locations:

- a. Connection point of new pipeline to existing pipeline.
- b. Crossing points of new pipeline with existing lines.

#### 3.5.5.5 Holiday Test

Any damage to the protective covering during transit and handling shall be repaired before installation. After field-coating and wrapping has been applied, the entire pipe shall 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 shall be equipped with a bell, buzzer, or other type of audible signal which sounds when a holiday is detected. Holidays in the protective covering shall be repaired upon detection. Occasional checks of holiday detector potential will be made by the Contracting Officer to determine suitability of the detector. Labor, materials, and equipment necessary for conducting the inspection shall be furnished by the Contractor. The coating system shall be inspected for holes, voids, cracks, and other damage during installation.

#### 3.5.5.6 Recording Measurements

All pipe- to-soil potential measurements, including initial potentials where required, shall be recorded. Locate, correct and report to the Contracting Officer any short circuits to foreign pipes encountered during checkout of the installed cathodic protection system. Pipe- to-soil potential measurements shall be taken on as many pipes as necessary to determine the extent of protection or to locate short-circuits.

### 3.6 TRAINING COURSE

Conduct a training course for the operating staff as designated by the Contracting Officer. The training period shall consist of a total of 4 hours of normal working time and shall start after the system is functionally completed but prior to final acceptance tests. Submit the proposed Training Course Curriculum (including topics and dates of discussion) indicating that all of the items contained in the operating and maintenance instructions, as well as demonstrations of routine maintenance operations, including testing procedures included in the maintenance instructions, are to be covered. The field instructions shall cover all of the items contained in the operating and maintenance instructions, as well as demonstrations of routine maintenance operations, including testing procedures included in the maintenance instructions. At least 14 days prior to date of proposed conduction of the training course, the training course curriculum shall be submitted for approval, along with the proposed training date. Training shall consist of demonstration of test equipment, providing forms for test data and the tolerances which indicate that the system works.

### 3.7 SYSTEM TESTING

Submit a report including potential measurements taken at adequately-close intervals to establish that minus 850 millivolts potential, "instant-off" potential, is provided, and that the cathodic protection is not providing interference to other foreign pipes causing damage to paint or pipes. The report shall provide a narrative describing how the criteria of protection is achieved without damaging other pipe or structures in the area.

### 3.8 SEEDING

Seeding shall be done as directed, in all unsurfaced locations disturbed by this construction. 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 should remain uncovered for more than two (2) days. The use of sod in lieu of seeding shall require approval by the Contracting Officer.

### 3.9 CLEANUP

The Contractor is responsible for cleanup of the construction site. All paper bags, wire clippings, etc., shall be disposed of as directed. Paper bags, wire clippings and other waste shall not be put in bell holes or anodes excavation.

-- 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

EUROPEAN UNION (EU)

Directive 2011/65/EU	(2011) Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment
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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 1598C (2014) Standard for Light-Emitting Diode (LED) Retrofit Luminaire Conversion Kits
- 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 RELATED REQUIREMENTS

Materials not considered to be luminaires, luminaire accessories, or lighting equipment are specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Luminaires and accessories that are mounted in exterior environments and not attached to the exterior of the building are specified in Section 26 56 00 EXTERIOR LIGHTING. Cybersecurity requirements are specified in Section 25 05 11.02. CYBERSECURITY FOR LOW IMPACT LIGHTING CONTROL SYSTEMS. Commissioning requirements are specified in Section 01 91 00.15 BUILDING COMMISSIONING.

1.3 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.

1.4 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 Notebook, 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

Lighting Control System One-Line Diagram; G

Sequence of Operation for Lighting Control System; G

SD-03 Product Data

Luminaires; G

Light Sources; G

LED Drivers; G  
Luminaire Warranty; G  
Lighting Controls Warranty; G  
Local Area Controller; G  
Lighting Control Panel; G  
Lighting Contactor; G  
Switches; G  
Digital Switch Timers; G  
Wall Box Dimmers; G  
Scene Wallstations; G  
Occupancy/Vacancy Sensors; G  
Photosensors; G  
Power Packs; G  
Power Hook Luminaire Hangers; G  
Exit Signs; G  
Emergency Drivers; G

SD-05 Design Data

Luminaire Design Data; G  
Photometric Plan; G

SD-06 Test Reports

ANSI/IES LM-79 Test Report; G  
ANSI/IES LM-80 Test Report; G  
ANSI/IES TM-21 Test Report; G  
ANSI/IES TM-30 Test Report; G  
Occupancy/Vacancy Sensor Verification Test; G  
Photosensor Verification Test; G

SD-07 Certificates

LED Driver and Dimming Switch Compatibility Certificate; G

SD-10 Operation and Maintenance Data



Lighting System, Data Package 5; G

Lighting Control System, Data Package 5; G

Maintenance Staff Training Plan; G

End-User Training Plan; G

## 1.5 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.

### 1.5.1 Luminaire Drawings

Include dimensions, accessories installation details, and construction details. Photometric data, including CRI, CCT, LED driver type, zonal lumen data, and candlepower distribution data must accompany shop drawings.

### 1.5.2 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.

### 1.5.3 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.

### 1.5.4 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.

### 1.5.5 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.

#### 1.5.6 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.

#### 1.5.7 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.

#### 1.5.8 Photometric Plan

##### 1.5.8.1 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.

##### 1.5.8.2 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.

#### 1.5.8.3 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.

#### 1.5.9 Occupancy/Vacancy Sensor Coverage Layout

Provide floor plans showing coverage layouts of all devices using manufacturer's product information.

#### 1.5.10 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.

#### 1.5.11 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.

#### 1.5.12 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.

#### 1.5.12.1 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.

#### 1.5.12.2 Material and Equipment Manufacturing Date

Do not use products manufactured more than six months prior to date of delivery to site, unless specified otherwise.

### 1.6 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.

#### 1.6.1 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.
- 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.

### 1.6.2 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.

## 1.7 OPERATION AND MAINTENANCE MANUALS

### 1.7.1 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.

### 1.7.2 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.

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

2.2.1.1 Luminaire Conversion Kits

Provide luminaire conversion kits that meet UL 1598C Standard for Light-Emitting Diode (LED) Retrofit Luminaire Conversion Kits.

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 as indicated on drawings (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 11.02 CYBERSECURITY FOR LOW IMPACT LIGHTING 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, and other control devices.

Enclose panel hardware in a surface-mounted, NEMA 1, 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 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 .
- 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 Scene Wallstations

Provide scene wallstations that are compatible with the other components of the lighting control system and capable of Class 1 or 2 wiring methods in accordance with the NEC and local codes. Provide devices that contain on/off group, preset scene functions, or dim up/dim down interface through front panel. Programming of new scenes or zone assignments must be accomplished by authorized personnel from the space being controlled. Provide labeling for each button, including laminated sheet with scene descriptions to be posted near each scene controller.

#### 2.5.2.5 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 120-277 volts.

- 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.

#### 2.5.2.5.1 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.

#### 2.5.2.5.2 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.

#### 2.5.2.5.3 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.

#### 2.5.2.5.4 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.

#### 2.5.2.5.5 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.

#### 2.5.2.6 Photosensors

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.
- b. UL listed for damp location.
- c. Configured for universal mounting.
- d. 6 inch high, 3/4 inch stroke red lettering on face of sign with chevrons on either side of lettering to indicate direction.

- e. 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. In lieu of battery, can use a nonradioactive photoluminescent plate.

#### 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 10 watts, 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.

### 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 11.02. CYBERSECURITY FOR LOW IMPACT LIGHTING CONTROL SYSTEMS for additional lighting control installation requirements.

##### 3.1.5.1 Scene Wallstations

Submit labeling templates for all scene wallstations, ganged faceplates and other manual control cover plates. Label each scene control button with approved scene description.

##### 3.1.5.2 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.

#### 3.1.5.3 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 26 56 00

EXTERIOR LIGHTING

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 ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS  
(AASHTO)

AASHTO LTS (2013; Errata 2013) Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals

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 B117 (2019) Standard Practice for Operating Salt Spray (Fog) Apparatus

EUROPEAN UNION (EU)

Directive 2011/65/EU (2011) Restriction of the Use of Certain 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 RP-8 (2018; Addenda 1 2020; Errata 1-2 2021) Recommended Practice for Design and Maintenance of Roadway and Parking Facility Lighting

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
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 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)	
ANSI C136.3	(2020) Roadway and Area Lighting Equipment - Luminaire Attachments
ANSI C136.13	(2020) Roadway and Area Lighting Equipment - Metal Brackets for Wood Poles
ANSI C136.21	(2014) American National Standard for Roadway and Area Lighting Equipment - Vertical Tenons Used with Post-Top-Mounted Luminaires
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 C136.31	(2023) Roadway and Area Lighting Equipment - Luminaire Vibration
NEMA ICS 2	(2000; R 2020) Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 V
NEMA IEC 60529	(2004) Degrees of Protection Provided by Enclosures (IP Code)
NEMA SSL 1	(2016) Electronic Drivers for LED Devices, Arrays, or Systems
NEMA SSL 3	(2011) High-Power White LED Binning for General Illumination

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

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

UNDERWRITERS LABORATORIES (UL)

UL 773 (2016; Reprint Jul 2020) UL Standard for  
Safety Plug-In, Locking Type Photocontrols  
for Use with Area Lighting

UL 773A (2016; Reprint Jan 2024) UL Standard for  
Safety Nonindustrial Photoelectric  
Switches for Lighting Control

UL 1310 (2018; Reprint Jun 2022) UL Standard for  
Safety Class 2 Power Units

UL 1598 (2021; Reprint Jan 2024) UL Standard for  
Safety Luminaires

UL 8750 (2015; Reprint Sep 2021) UL Standard for  
Safety Light Emitting Diode (LED)  
Equipment for Use in Lighting Products

1.2 RELATED REQUIREMENTS

Materials not considered to be luminaires, luminaire accessories, or lighting equipment are specified in Section(s) 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION . Luminaires and accessories installed in interior of buildings or attached to the exterior of a building are specified in Section 26 51 00 INTERIOR LIGHTING. Commissioning requirements are specified in Section 01 91 00.15 BUILDING COMMISSIONING.

1.3 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.

1.4 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 Notebook, 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

Pole Drawings; G

Control System One-Line Diagram; G

Sequence of Operation for Exterior Lighting Control System; G

SD-03 Product Data

Luminaires; G

Light Sources; G

LED Drivers; G

Luminaire Warranty; G

Lighting Controls Warranty; G

Pole Warranty; G

Photosensors; G

Lighting Contactor; G

Poles; G

Brackets

SD-05 Design Data

Luminaire Design Data; G

Photometric Plan; G

SD-06 Test Reports

ANSI/IES LM-79 Test Report; G

ANSI/IES LM-80 Test Report; G

ANSI/IES TM-21 Test Report; G

SD-08 Manufacturer's Instructions

Poles

SD-10 Operation and Maintenance Data

Lighting System, Data Package 5; G

Exterior Lighting Control System, Data Package 5; G

Maintenance Staff Training Plan; G

End-User Training Plan; G

1.5 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.

1.5.1 Drawing Requirements

1.5.1.1 Luminaire Drawings

Include dimensions, effective projected area (EPA), weight, accessories, and installation and construction details. Photometric data, including CRI, CCT, TM-15-11 BUG rating, LED driver type, aiming diagram, zonal lumen data, and candlepower distribution data per LM-79 must accompany shop drawings.

1.5.1.2 Pole Drawings

Include dimensions, wind load determined in accordance with AASHTO LTS, pole deflection, pole class, and other applicable information.

1.5.2 Luminaire Design Data

- a. Provide distribution data according to IES classification type as defined in IES Lighting Library and ANSI/IES RP-8.
- b. B.U.G. rating for the installed position as defined by ANSI/IES TM-15 and shielding as defined by ANSI/IES RP-8.
- c. Provide safety certification and file number for the luminaire family. Include listing, labeling and identification in accordance with NFPA 70 (NEC). 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).
- d. 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.

- e. Provide wind loading calculations for luminaires mounted on poles. Weight and effective projected area (EPA) of luminaires and mounting brackets must not exceed maximum rating of pole as installed in particular wind zone area.

#### 1.5.3 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 as outlined under "14.0 Test Report" in ANSI/IES LM-79.

#### 1.5.4 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.

#### 1.5.5 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.

#### 1.5.6 Photometric Plan

For parking lots include computer-generated photometric analysis of the "designed to" values in accordance with ANSI/IES RP-8 for the "end of useful life" of the luminaire installation using a light loss factor of 0.81. Provide photometric plans that meet criteria in the Basis of Design in the project plans. Include the following in the submittal:

- a. Horizontal illuminance measurements at finished grade, taken at a maximum grid size of 10 feet by 10 feet.
- b. Vertical illuminance measurements at 5 feet above finished grade at all sidewalks and crosswalks, taken at a maximum of 10 feet.
- c. Minimum and maximum footcandle levels.
- d. Average maintained footcandle level.
- e. Maximum to minimum ratio for horizontal illuminance only.

#### 1.5.7 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.
- b. One of the qualified labs listed on the Department of Energy - Energy

Efficiency & Renewable Energy, Solid-State Lighting web site.

- c. One of the EPA-Recognized Laboratories listed at for LM-80 testing.

#### 1.5.8 Regulatory Requirements

Equipment, materials, installation, and workmanship must be in accordance with the mandatory 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.

#### 1.5.9 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.

##### 1.5.9.1 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.

##### 1.5.9.2 Material and Equipment Manufacturing Date

Do not use products manufactured more than six months prior to date of delivery to site, unless specified otherwise.

#### 1.6 DELIVERY, STORAGE, AND HANDLING OF POLES

##### 1.6.1 Steel Poles

Do not store poles on ground. Support poles so they are at least one foot above ground level and growing vegetation. Do not remove factory-applied pole wrappings until just before installing pole.

#### 1.7 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.

##### 1.7.1 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.
- 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 installation.

#### 1.7.2 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 photosensors and motion sensors.
- 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.

### 1.7.3 Pole Warranty

Provide and transfer to the government the original pole manufacturers standard commercial warranty for each different pole 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. Provide a written ten year minimum replacement warranty for material, luminaire finish, and workmanship. Warranty service must be performed by a factory-trained engineer or technician.

## 1.8 OPERATION AND MAINTENANCE MANUALS

### 1.8.1 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. 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.

### 1.8.2 Exterior Lighting Control System

Provide operation and maintenance manuals for the exterior 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 exterior lighting control system. Include the following:

- a. Control System One-Line Diagram
- b. Product data for all devices, including installation and programming instructions.
- c. Training materials, such as videos or in-depth manuals, that cover basic operation of the lighting control system and instructions on modifying the control system. Training materials must include calibration, adjustment, troubleshooting, maintenance, repair, and replacement.

## 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 XL 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 LED 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. Housing 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
Area and Roadway (pole mounted, arm mounted)	119 LPW
Pedestrian Post-Top (pole mounted, arm mounted)	97 LPW
Bollard	45 LPW
Accent (adjustable landscape, sign lighting)	35 LPW
Linear Accent (facade, wallwash)	80 LPW
Exterior Wall Sconce	50 LPW
Steplight	30 LPW
Parking Garage Luminaire	113 LPW

- e. Product rated for operation within an ambient temperature range of minus 22 degrees F to 104 degrees F.
- f. UL listed for wet locations. Optical compartment for LED luminaires must be sealed and rated a minimum of IP65 per NEMA IEC 60529.
- g. IES Lighting Library. Light distribution and NEMA field angle classifications as indicated in luminaire schedule on project plans.
- h. Housing finish that is baked-on enamel, anodized, or baked-on powder coat paint. Finish must be capable of surviving ASTM B117 salt fog environment testing for 2500 hours minimum without blistering or peeling.
- i. LED driver and light source package, array, or module are accessible for service or replacement without removal or destruction of luminaire.
- j. ANSI/IES TM-15. Does 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
Area and Roadway	All	B3-U0-G3
Pedestrian Post-Top	All	B2-U1-G1
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

- k. Fully assembled and electrically tested prior to shipment from factory.
- l. Finish color is as indicated in the luminaire schedule or detail on the project plans.
- m. Lenses constructed of clear tempered glass or UV-resistant acrylic.
- n. All factory electrical connections are made using crimp, locking, or latching style connectors. Twist-style wire nuts are not acceptable.
- o. NEMA C136.31. Comply with 3G vibration testing.
- p. Luminaire arm bolts constructed from 304 stainless steel or zinc-plated steel.

### 2.3 LIGHT SOURCES

NEMA ANSLG C78.377, NEMA SSL 3. Provide type, lumen rating, and wattage as indicated in 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 Correlated Color Temperature (CCT) of as indicated on drawings (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 4-step McAdam ellipse.

### 2.4 LED DRIVERS

NEMA SSL 1, UL 1310. Provide LED Drivers that are electronic, UL Class 1



or Class 2, constant-current type and meet the following requirements:

- a. The combined LED driver and LED light source system is greater than or equal to the minimum luminaire efficacy values as listed in the luminaire schedule provided.
- b. Operate at a voltage of 120-277 volts at 50/60 hertz, with input voltage fluctuations of plus or 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 or equal to 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. Meets the "Elevated" (10kV/10kA) requirements per IEEE C62.41.2 -2002. Manufacturer must indicate whether failure of the electrical immunity system can possibly result in disconnect of power to luminaire. Provide surge protection that is integral to the LED driver.
- g. Contains 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. Complies with the requirements of the Federal Communications Commission (FCC) rules and regulations, Title 47 CFR part 15, Non-Consumer (Class A) for EMI/RFI (conducted and radiated).
- i. Class A sound rating for all drivers mounted under a covered structure, such as a canopy, or where otherwise appropriate.
- j. Directive 2011/65/EU. Restriction of Hazardous Substances (RoHS) compliant.
- k. UL listed for wet locations typical of exterior installations.
- l. Dimmable, and compatible with a standard dimming control circuit of 0 - 10V.
- m. Rated to operate between ambient temperatures of minus 22 degrees F and 104 degrees F.

#### 2.4.1 Remote LED Drivers

Provide remote LED Drivers that are UL listed for wet locations typical of exterior installations.

### 2.5 LIGHTING CONTROLS

#### 2.5.1 System

Provide exterior lighting control system that operates the exterior lighting system as described in the exterior lighting control strategies

in the project plans. Submit Sequence of Operation for Exterior Lighting Control System describing the operation of the proposed exterior lighting control system and devices. Sequence of Operation must provide the strategies identified in the exterior lighting control strategies.

## 2.5.2 Devices

### 2.5.2.1 Photosensors

UL 773, UL 773A. Provide Photosensors that meet the following requirements:

- a. Hermetically sealed, cadmium sulfide or silicon diode light sensor type, 50/60 Hz with single-pole, single or double-throw contacts.
- b. Turns ON at 1 to 3 footcandles and turns OFF at 3 to 15 footcandles.
- c. Designed to fail to the ON position.
- d. Housing is constructed of polycarbonate, rated to operate within a temperature range of minus 40 to 158 degrees F.
- e. Time delay that prevents accidental switching from transient light sources.
- g. Designed for 20-year service to match life expectancy of long-life LED fixtures and exceed 15,000 operations at full load. Provide photosensors with zero-cross technology to withstand severe in-rush current and extend relay life.
- h. Swivel base type housing with 1/2 in threaded base for mounting to a junction box or conduit.
- j. Provide photosensors with metal oxide varistor (MOV) type surge protection.

### 2.5.2.2 Lighting Contactor

NEMA ICS 2. Provide a electrically-held lighting contactor housed in a NEMA 1 enclosure conforming to NEMA ICS 6. Contactor must have 4 poles, configured as normally open (NO). Contacts must be rated 600 volts, 30 amperes for a resistive load. Coil operating voltage must be 277 volts. Contactor must have silver cadmium oxide double-break contacts and must require no arcing contacts.

## 2.6 POLES

AASHTO LTS. Provide round straight poles designed for wind loading of 100 miles per hour while supporting luminaires and all other appurtenances indicated. The effective projected areas (EPA) of luminaires and appurtenances used in calculations must be specific for the actual products provided on each pole. Provide poles that are anchor-base type designed for use with underground supply conductors. Poles must have oval-shaped hand hole having a minimum clear opening of 3 by 5 inches. Secure hand hole covers by stainless steel captive screws. Provide metal poles with an internal grounding connection accessible from the hand hole near the bottom of each pole. Install a means of wire disconnection accessible from the hand hole. Do not install square poles. Provide poles from a Manufacturer with a standard provision for protecting the

finish during shipment and installation. Do not install scratched, stained, chipped, or dented poles.

#### 2.6.1 Steel Poles

Provide steel poles with hot-dipped galvanized in accordance with ASTM A123/A123M factory finish. Provide poles that meet the following requirements:

- a. Minimum 11-gage steel with minimum yield/strength of 48,000 psi
- b. Pole is mounted by anchor bolts.
- c. Consists of tapered tubular members, either round in cross section or polygonal.
- d. Pole shaft is one piece and is of welded construction with no bolts, rivets, or other means of fastening except as specifically approved.
- e. Base covers are of structural quality hot-rolled carbon steel plate, with a minimum yield of 36,000 psi.
- f. Markings are approximately 3 to 4 feet abovegrade and includes manufacturer, year of manufacture, top and bottom diameters, and length.
- g. Grounding connection is designed to prevent electrolysis when used with copper ground wire.

#### 2.6.2 Brackets and Supports

ANSI C136.3, ANSI C136.13, and ANSI C136.21. Provide pole brackets that are not less than 1 1/4 inch galvanized steel pipe secured to pole. Slip-fitter or pipe-threaded brackets may be used, but brackets must be coordinated to luminaires provided, and brackets for use with one type of luminaire must be identical. Brackets for pole-mounted street lights must correctly position luminaire no lower than mounting height indicated. Mount brackets not less than 24 feet above street. Provide special mountings or brackets as indicated and of metal which will not promote galvanic reaction with luminaire head.

#### 2.6.3 Pole Foundations

Provide anchor bolts consisting of a steel rod with a minimum yield strength of 50,000 psi; the top 12 inches of the rod must be galvanized in accordance with ASTM A153/A153M. Concrete must be as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE and Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

### 2.7 EQUIPMENT IDENTIFICATION

#### 2.7.1 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.

## 2.7.2 Labels

UL 1598. Luminaires must be clearly marked for operation of specific light sources and drivers according to proper light source type. Note the following luminaire characteristics in the format "Use Only \_\_\_\_\_":

- a. Correlated color temperature (CCT) and color rendering index (CRI) for all luminaires.
- b. Driver and dimming protocol.

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.

## 2.8 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

#### 3.1.1 Luminaires

Install all luminaires in accordance with the luminaire manufacturer's written instructions. Install all luminaires at locations and heights as indicated on the project plans. Level all luminaires in accordance to manufacturer's written instructions.

#### 3.1.2 LED Drivers

Provide LED drivers integral to luminaire as constructed by the manufacturer.

#### 3.1.3 Pole Setting

Poles in straight runs must be in a straight line. Dig holes large enough to permit the proper use of tampers to the full depth of the hole. Place backfill in the hole in 6 inch maximum layers and thoroughly tamp. Place surplus earth around the pole in a conical shape and pack tightly to drain water away.

#### 3.1.4 Lighting Controls

##### 3.1.4.1 Photosensors

Aim photosensor according to manufacturer's recommendations.

##### 3.1.4.2 Motion Sensors

Locate sensors in accordance with the manufacturer's recommendation. Locate sensors to achieve coverage of areas as indicated on project plans. Coverage patterns must be derated as recommended by manufacturer

based on mounting height of sensor and any obstructions such as trees. Do not use gross rated coverage in manufacturer's product literature.

### 3.1.5 Grounding

Ground noncurrent-carrying parts of equipment including metal poles, luminaires, mounting arms, brackets, and metallic enclosures as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION. Where copper grounding conductor is connected to a metal other than copper, provide specially treated or lined connectors suitable for this purpose.

## 3.2 FIELD QUALITY CONTROL

### 3.2.1 Tests

Upon completion of installation, verify that equipment is properly installed, connected, and adjusted. Perform initial operational test, consisting of the entire system energized for 72 consecutive hours without any failures of any kind occurring in the system. All circuits must test clear of faults, grounds, and open circuits.

#### 3.2.1.1 Lighting Control Verification Test

Verify lighting control system and devices operate according to approved sequence of operations. Verification tests are to be completed after commissioning.

## 3.3 CLOSEOUT ACTIVITIES

### 3.3.1 Training

Provide on-site training to the Owner's personnel in the operation and maintenance of lighting and lighting control system. Provide training that includes calibration, adjustment, troubleshooting, maintenance, repair, and replacement.

#### 3.3.1.1 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 demonstrate 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.

#### 3.3.1.2 End-User Training

Submit a 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 demonstration for each type of user interface. Provide users with the curfew 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.

-- 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 IPTV utilizing CAT6 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 information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. 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 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-83-596 (2021) Indoor Optical Cable

ICEA S-90-661 (2021) Category 3 and 5E Individually Unshielded Twisted Pairs, Indoor Cables (With or Without an Overall Shield) for Use in General Purpose and LAN Communications Wiring Systems

NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION (NECA)

NECA/BICSI 568 (2006) Standard for Installing Building Telecommunications Cabling

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI/NEMA WC 66 (2019) 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; R 2022) Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant, Adoption of IEC 61280-4-2

	edition 2: Fibre-Optic Communications Subsystem Test Procedures - Part 4-2: Installed Cable Plant - Single-Mode Attenuation and Optical Return Loss Measurement
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/EIA-598	(2014D; Add 2 2018) Optical Fiber Cable Color Coding
TIA-606	(2021d) Administration Standard for Telecommunications Infrastructure
TIA-607	(2019d) Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises
TIA-1152	(2016; R 2021) 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)
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UNDERWRITERS LABORATORIES (UL)

UL 50	(2024) UL Standard for Safety Enclosures for Electrical Equipment, Non-Environmental Considerations
UL 444	(2017; Reprint Jun 2021) UL Standard for Safety 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 May 2023) UL Standard for Safety Marking and Labeling Systems
UL 1286	(2022; Reprint Mar 2024) UL Standard for Safety Office Furnishings
UL 1666	(2007; Reprint Sep 2021) UL Standard for Safety Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts
UL 1863	(2004; Reprint Oct 2019) 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 information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. 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

Spare Parts

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

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.

Connector Blocks

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 Backbone Cabling 2.3.1.1 Backbone Copper

Copper backbone cable shall be solid conductor, 24 AWG, 100 ohm, 50 -pair, Category 3, UTP, in accordance with ICEA S-90-661, TIA-568-C.1, TIA-568-C.2 and UL 444, formed into 25 pair binder groups covered with a gray thermoplastic jacket. Cable shall be imprinted with manufacturers name or identifier, flammability rating, gauge of conductor, transmission performance rating (category designation) at regular length marking 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.

### 2.3.1.2 Backbone Optical Fiber

Provide in accordance with ICEA S-83-596, TIA-568-C.3, UL 1666 and NFPA 70. Cable shall be imprinted with fiber count, fiber type and aggregate length at regular intervals not to exceed 40 inches.

Provide the number of strands indicated, (but not less than 12 strands between the main telecommunication room and each of the other telecommunication rooms), of single-mode(OS1), tight buffered fiber optic cable.

Provide plenum (OFNP), riser (OFNR), or general purpose (OFN or OFNG) rated non-conductive, fiber optic cable in accordance with NFPA 70. Substitution of a higher rated cable shall be permitted in accordance with NFPA 70. The cable cordage jacket, fiber, unit, and group color shall be in accordance with TIA/EIA-598.

Provide plenum (OFNP) riser (OFNR) , or general purpose (OFN or OFNG) rated non-conductive, fiber optic cable in accordance with NFPA 70. Substitution of a higher rated cable shall be permitted in accordance with NFPA 70. The cable cordage jacket, fiber, unit, and group color shall be in accordance with TIA/EIA-598.2.3.2 Horizontal Cabling

Provide horizontal cable in compliance with NFPA 70 and performance characteristics in accordance with TIA-568-C.1.

### 2.3.2.1 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 ablu 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.

#### 2.3.2.2 Horizontal Optical Fiber

Provide optical fiber horizontal cable in accordance with ICEA S-83-596 and TIA-568-C.3. Cable shall be tight buffered, multimode, 50/125-um diameter laser optimized, OM3. Cable shall be imprinted with manufacturer, flammability rating and fiber count at regular intervals not to exceed 40 inches.

Provide plenum (OFNP), riser (OFNR), or general purpose (OFN or OFNG) rated non-conductive, fiber optic cable 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 be UL listed and labeled for wet locations in accordance with NFPA 70. The cable jacket shall be of single jacket construction with color coding of cordage jacket, fiber, unit, and group in accordance with TIA/EIA-598.

#### 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.

##### 2.4.5 Optical Fiber Distribution Panel

Rack mounted optical fiber distribution panel (OFDP) shall be constructed in accordance with ECIA EIA/ECA 310-E utilizing 16 gauge steel or 11 gauge aluminum minimum. Panel shall be divided into two sections, distribution and user. Distribution section shall have strain relief, routing guides, splice tray and shall be lockable, user section shall have a cover for patch cord protection. Each panel shall provide 24 strand single-mode pigtailed and adapters. Provide adapters as duplex LC with zirconia ceramic alignment sleeves. Provide dust covers for adapters. Provide patch cords as specified in the paragraph PATCH PANELS.

#### 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 1310and 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 ivto 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 10 05

ELECTRONIC SECURITY SYSTEMS (ESS)  
05/16

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

ASTM B32 (2020) Standard Specification for Solder Metal

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 802.3 (2022) Ethernet

IEEE C2 (2023) National Electrical Safety Code

INTELLIGENCE COMMUNITY STANDARD (ICS)

ICS 705-1 (2010) Physical and Technical Security Standard for Sensitive Compartmented Information Facilities

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ANSI ISO/IEC 7816 (R 2009) Identification Cards - Integrated Circuit Cards

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250 (2020) Enclosures for Electrical Equipment (1000 Volts Maximum)

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

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

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



NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST FIPS 201-2 (2013) Personal Identity Verification  
(PIV) of Federal Employees and Contractors

OPEN NETWORK VIDEO INTERFACE FORUM (ONVIF)

ONVIF (2017) Core Specification Version 17.06

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-222 (2018H; Add 1 2019) Structural Standard  
for Antenna Supporting Structures and  
Antennas and Small Wind Turbine Support  
Structures

TIA-568-C.2 (2009; Errata 2010; Add 2 2014; Add 1  
2016) Balanced Twisted-Pair  
Telecommunications Cabling and Components  
Standards

TIA-606 (2021d) Administration Standard for  
Telecommunications Infrastructure

U.S. DEPARTMENT OF DEFENSE (DOD)

DODI 8500.01 (2014) Cybersecurity

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

47 CFR 15 Radio Frequency Devices

UNDERWRITERS LABORATORIES (UL)

UL 50 (2024) UL Standard for Safety Enclosures  
for Electrical Equipment,  
Non-Environmental Considerations

UL 294 (2023) UL Standard for Safety Access  
Control System Units

UL 634 (2007; Reprint Mar 2015) Connectors and  
Switches for Use with Burglar-Alarm Systems

UL 639 (2007; Reprint Nov 2019) Standard for  
Intrusion Detection Units

UL 681 (2014; Reprint Jan 2021) UL Standard for  
Safety Installation and Classification of  
Burglar and Holdup Alarm Systems

UL 796 (2020; Reprint Oct 2023) UL Standard for  
Safety Printed Wiring Boards

UL 969 (2017; Reprint May 2023) UL Standard for  
Safety Marking and Labeling Systems

UL 1037 (2016; Reprint Aug 2023) UL Standard for

Safety Antitheft Alarms and Devices

- UL 1076 (2018; Reprint Feb 2021) UL Standard for Safety Proprietary Burglar Alarm Units and Systems
- UL 1610 (2016; Reprint Apr 2021) UL Standard for Safety Central-Station Burglar-Alarm Units

1.2 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. 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

- ESS Components; G
- Overall System Schematic; G

SD-03 Product Data

- Premise Control Unit; G
- Detection Sensors; G
- Access Control Unit; G
- Access Control Devices; G
- Cameras; G
- Camera Lenses; G
- Camera Housing and Mounts; G
- Thermal Imaging System; G
- Video Recording; G
  
- Uninterruptible Power Supply (UPS); G
- Batteries; G
- Component Enclosure; G
- Equipment Rack; G
- Communications Interface Devices
- Video And Ess Transmission

SD-05 Design Data

Backup Battery Capacity Calculations; G  
Access Control Throughput Rates; G  
CCTV Storage Calculations

SD-07 Certificates

Contractor Qualifications; G  
Instructor Qualifications; G  
Data Encryption; G

SD-10 Operation and Maintenance Data

ESS Components and ESS Software: Data Package 4; G  
ESS Software and ESS Components: Data Package 4; G

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

SD-11 Closeout Submittals

As-Built Drawings; G

1.3 QUALITY ASSURANCE

1.3.1 Regulatory Requirements

The advisory provisions in each of the publications referred to in this specification are mandatory. Interpret these publications as though the word "must" has 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.

1.3.2 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 and:

- a. Have been in satisfactory commercial or industrial use for 2 years prior to bid opening, and have been utilized in applications of equipment and materials under similar circumstances and of similar size.
- b. Have been available 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.

- d. Provide commercial off-the-shelf (COTS) products in which the manufacturer allows a network of qualified distributors to sell, install, integrate, maintain, and repair the hardware and software products that make up the system.

#### 1.3.2.1 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.

#### 1.3.2.2 Material and Equipment Manufacturing Date

Products manufactured more than one year prior to date of delivery to the site are not acceptable.

#### 1.3.2.3 Product Safety

System components are to conform to applicable rules and requirements of NFPA 70. Equip system components with instruction stickers including warnings and cautions describing physical safety, and special or important procedures to be followed in operating and servicing system equipment.

#### 1.3.3 Shop Drawings

##### 1.3.3.1 ESS Components

Submit the ESS Components, Data Package 4 with the ESS Software submittal package in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. Submit drawings that clearly and completely indicate each ESS component function that includes:

- a. Termination device points
- b. Interconnections required for system operation
- c. Interconnections between modules and devices
- d. Proposed wireway or conduit systems to be used including:
  - (1) Locations
  - (2) Sizes
  - (3) Types
- e. Drawings showing:
  - (1) Device locations and spacing
  - (2) Mounting and positioning details
  - (3) Riser Diagrams with cable sizes and types
  - (4) Bill of Materials (Device make, model and quantities)

(5) Alarm and access control zones

(6) CCTV and sensor coverage areas

(7) Spare capacity

#### 1.3.3.2 Overall System Schematic

Indicate the relationship of integrated components on one-line diagram and show:

- a. Power source
- b. System controls
- c. Impedance matches
- d. Interconnecting wire data including:
  - (1) Number
  - (2) Size
  - (3) Identification
  - (4) Maximum lengths

#### 1.3.4 Evidence of Experience and Qualifications

##### 1.3.4.1 Contractor Qualifications

Submit experience and certified qualifications data prior to installation. Show that specific installers who will perform the work have a minimum of 2 years of experience successfully installing ESS of the same type and similar design as specified. Include the names, locations, and points of contact of at least two installations of similar type and design as specified in this document where the installer has installed such systems. Indicate the type of each system installed. Certify that each system has performed satisfactorily in the manner intended for a period of at least 12 months.

##### 1.3.4.2 Instructor Qualifications

Submit the instructor's experience and certified qualifications data prior to installation. Show that the instructor has received a minimum of 24 hours of ESS training from a technical organization such as the National Burglar and Fire Alarm Association, and 2 years experience in installing the specified ESS type.

#### 1.4 Environmental Conditions

##### 1.4.1 Interior Conditions

Equipment installed in environmentally protected interior areas must meet performance requirements specified for the following ambient conditions:

###### 1.4.1.1 Temperature

32 to 120 degrees F. Components installed in unheated security protected

areas must meet performance requirements for temperatures as low as 0 degrees F

1.4.1.2 Pressure

Sea level to 15,000 feet above sea level

1.4.1.3 Relative Humidity

5 to 95 percent

1.4.1.4 Fungus

Components must be constructed of nonfungus nutrient materials or be treated to inhibit fungus growth

1.4.1.5 Acoustical Noise

Components must be suitable for use in high noise areas above 100 dB, without adversely affecting their performance

1.4.2 Exterior Conditions

Components in enclosures must meet performance requirements when exposed to the following ambient conditions:

1.4.2.1 Temperature

Minus 25 to 140 degrees F

1.4.2.2 Pressure

Sea level to 15,000 feet above sea level

1.4.2.3 Solar Radiation

Six hours of solar radiation per day at dry bulb temperature of 120 degrees F including 4 hours of solar radiation at 104 watts per square foot

1.4.2.4 Sand and Dust

Wind driven for up to 6miles per hour (mph)

1.4.2.5 Rain

2 inches per hour and 5 inches per hour cyclic with wind plus one period of 12 inches per hour

1.4.2.6 Humidity

5 to 95 percent

1.4.2.7 Fungus

Warm, humid atmosphere conducive to the growth of heterotropic plants

1.4.2.8 Salt Fog

Salt atmosphere with 5 percent salinity

1.4.2.9 Snow

Snow loading of 48 (psf) per hour; blowing snow of 4.6 psf per hour

1.4.2.10 Ice Accretion

Up to 1/2 inches of radial ice

1.4.2.11 Wind

Continual velocity up to 50 mph with gusts to 66 mph, except that fence sensors must detect intrusions up to 35 mph

1.4.2.12 Acoustical Noise

Components must be suitable for use in high noise areas above 110 dB without adversely affecting their performance. Examples areas include flight lines, runup pads, and generator sites.

1.5 SYSTEM CALCULATIONS AND ANALYSIS

1.5.1 Backup Battery Capacity Calculations

Submit calculations showing that backup battery capacity exceeds sensor operation, communications supervision, and alarm annunciation power requirements for proposed equipment plus 25 percent spare capacity.

1.5.2 CCTV Storage Calculations

Submit calculations showing the required storage capacity for each video storage device.

1.6 ESS SOFTWARE, DATA PACKAGE 4

Submit the ESS software, Data Package 4 with the ESS Components submittal package in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. Describe the functions of all software in the software manual and include:

- a. All information necessary to enable proper loading, testing, and operation
- b. Terms and functions definitions
- c. Use of system and application software
- d. Procedures for system initialization, start-up and shutdown
- e. Alarm reports
- f. Reports generation
- g. Database format and data entry requirements
- h. Directory of all files
- i. All communication protocol descriptions, including data formats, command characters, and a sample of each type of data transfer

- j. Interface definition
- k. List of software keys

#### 1.7 AS-BUILT DRAWINGS

Maintain a separate set of drawings, elementary diagrams, and wiring diagrams of the system to be used for as-built drawings. Keep this set accurately and neatly up-to-date with all changes and additions. This set is not to be used for installation purposes.

Finish the final drawings submitted with the endurance test report in accordance with Section 01 78 00 CLOSEOUT SUBMITTALS for as-built requirements.

### PART 2 PRODUCTS

#### 2.1 SYSTEM DESCRIPTION

Provide a complete and integrated electronic security system (ESS). ESS must be compatible with the Installation's central monitoring system and monitored at the Installation central monitoring station. ESS consisting of the following subsystems and features:

- a. Intrusion Detection System (IDS)
- b. Access Control System (ACS)
- c. Closed-circuit Television System (CCTV)
- d. Security Command Center (SCC)
- e. Communications System

#### c. Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM

#### 2.2 PERFORMANCE REQUIREMENTS

Integrate the installed and operating subsystems into the overall ESS system to detect intrusion, control access, provide CCTV surveillance, provide visual verification, and perform as an entity, as specified below. Provide electronic equipment that complies with 47 CFR 15 and are suitable for the environment where they will be installed.

##### 2.2.1 Growth Capability

Provide capability for modular ESS expansion of inputs, outputs, card readers, and remote control stations with minimal equipment modification.



Software must be able to handle design requirements plus 25 percent spare capacity. Growth capability is not to be limited by the provided products.

#### 2.2.2 Hazardous Locations

When located in areas where fire or explosion hazards exist, provide system components rated and installed according to Chapter 5 of NFPA 70.

#### 2.2.3 Network Certification

Certify all Platform Information Technology (PIT) in accordance with DODI 8500.01 and the individual service implementation policy.

#### 2.2.4 Maintainability

Provide components that can be maintained using commercially available tools and equipment. Arrange and assemble components to be readily accessible to maintenance personnel without compromising system defeat resistance and with no degradation in tamper protection, structural integrity, EMI or RFI attenuation, or line supervision after maintenance when it is performed in accordance with manufacturer's instructions.

#### 2.2.5 Availablity

Provide components rated for continuous operation. Provide solid-state electronic components mounted on printed circuit boards, conforming to UL 796. Provide boards that are plug-in, quick-disconnect type. Do not impede maintenance with densely packed circuitry. Provide power-dissipating components with safety margins of not less than 25 percent with respect to dissipation ratings, maximum voltages, and current-carrying capacity. Provide solid-state type or hermetically sealed electromechanical type light duty relays and similar switching devices.

#### 2.2.6 Fail-Safe Capability

Provide fail-safe capability in critical elements of the ESS including, but not be limited to, the capability to monitor communication link integrity and to provide self-test. Provide fault annunciation when diminished functional capabilities are detected. Annunciate fail-safe alarms to clearly distinguish from other types of alarms.

#### 2.2.7 Line Supervision

Provide the same geographic resolution for fault isolation at the systems level as provided for intrusion detection. Provide either a static or dynamic system with active mode for line supervision of communication links of the ESS.

- a. The static system must represent "no-alarm" always by the same signal, which is different than the originally transmitted signal.
- b. The dynamic system must represent "no-alarm" with a signal which continually changes with time.

#### 2.2.8 Power Loss Detection

Detect AC and DC power loss and generate an alarm when a critical component of the system experiences temporary or permanent loss of power. Annunciate the alarm in the Security Command Center to clearly identify

the component experiencing power loss.

#### 2.2.9 Controls and Designations

Provide controls and designations as specified in NEMA ICS 1.

#### 2.2.10 Special Test Equipment

Provide all special test equipment, special hardware, software, tools, and programming or initialization equipment needed to start or maintain any part of the system and its components. Special test equipment is defined as any test equipment not normally used in an electronics maintenance facility.

#### 2.2.11 Electromagnetic Interference (EMI)

Configure and provide ESS components employing electromagnetic radiation constructed to provide minimal vulnerability to electronic countermeasures.

#### 2.2.12 Electromagnetic Radiation (EMR)

Provide only ESS communication components which are Federal Communications Commission (FCC) licensed and approved. Provide system components which are electromagnetically compatible.

#### 2.2.13 Interchangeability

Use off-the-shelf components which are physically, electrically, and functionally interchangeable with equivalent components as complete items. Equivalent, replacement components must not require new or other component modification. Do not use custom designed or one-of-a-kind items. Interchangeable components or modules must not require trial and error matching in order to meet integrated system requirements, system accuracy, or restore complete system functionality.

### 2.3 INTRUSION DETECTION SYSTEM (IDS)

The IDS primary function is to detect intrusion into secured areas. Utilize a single database for all IDS programming data that seamlessly integrates with the ESS under a single operating environment. The IDS events must be viewable as separate or as a combined list of all ESS events. Control the IDS alarm monitoring through software control from the ESS.

- a. Provide both supervised and non-supervised alarm point monitoring.
- b. Secure or access alarm points both manually and automatically by time of day, day of week or by operator command.

#### 2.3.1 IDS Components

Provide components:

- a. Premise Control Units (PCU)
- b. Detection Sensors
- c. Tamper Switches

### 2.3.2 Detection Sensitivity

The sensitivity of the IDS must allow for the following:

- b. Locating intrusions at individually protected assets or at an individual portal
- c. Locating intrusions within the coverage on a single volumetric sensor
- d. Locating failures or tampering at individual sensors

### 2.3.3 Detection Alarm and Reporting Capacity

Collect, communicate, and display up to 12 sensor zone alarms and to enable control of threecard readers and fourcard reader with integral keypad for secure and access inside of the protected area with a delayed alarm.

Identify individual sensors in alarm if the sensor zone is a multiple alarm source combination. Annunciate a single alarm within 1 seconds maximum, after sensor transducer or other detection device activation except that alarms transmitted by radio frequency signaling must communicate in less than 3 seconds.

### 2.3.4 False Alarm Rate

The false alarm rate for each interior IDS zone must not exceed one false alarm per 30-day period. The false alarm rate for each exterior IDS zone must not exceed one false alarm per 24-hour period.

### 2.3.5 Nuisance Alarm Rate

The nuisance alarm rate for each interior IDS zone must not exceed three nuisance alarms per 30-day period. The nuisance alarm rate for each exterior IDS zone must not exceed three nuisance alarms per 24-hour period.

### 2.3.6 Premise Control Unit (PCU)

Install the PCU command processor in a tamper resistant enclosure that is specified in paragraph "Component Enclosure". Package the following with the PCU:

- a. Power transformer
- b. Battery(s)
- c. Network connection cable
- d. Keypad(s)
- e. Keypad connection cable(s)
- f. Additional components as required for full functionality

#### 2.3.6.1 PCU Capabilities

Provide the PCU at a minimum but not limited to, the following

capabilities;

- a. Expansion to a total of at least 10,000 user codes with 99 user profile definitions.
- b. Support 4 keypads with alphanumeric display. Each keypad must be capable of securing and accessing any system area based on a pass code or access control card and or key FOB authorization. Provide keypad alphanumeric display with complete prompt messages during all stages of operation and system programming and display all relevant operating and test data.
- c. Four 4 shift schedules per area.
- d. A total of at least 100 programmable output relay schedules.
- e. 32 individual reporting areas.
- f. Data line supervision .
- g. Two-man access code or credentials.
- h. Support programming to require the same or different access code entered within a programmed delay time of 1 to 15 minutes after disarming before activating a silent ambush alarm.
- i. Support area programming that disables schedule and time-of-day changes while system is armed so that area can only be disarmed during scheduled times.
- j. Provide a minimum of a 4,000 event log buffer per PCU. Record and hold alarm activity information in the log buffer until the ESS is connected and receives the information. Provide a software-configurable warning log buffer filling notification for PCU(s) configured with network switch capabilities.
- k. Support a Network Interface Card (NIC) plug-in module with built in network router capable of 128 Bit AES Rijndael Encryption process certified by NIST (National Institute of Standards and Technology).

#### 2.3.6.2 Overcurrent Protection and Indication

When overcurrent more than it is rated for is detected by the PCU, communication bus(es) and keypad(s) are to be shut down and an overcurrent notification LED lit to indicate the situation.

#### 2.3.6.3 Manual and Self-Test

All testing from any alphanumeric keypad include testing for: standby battery, alarm bell or siren, and communication to the Security Command Center (SCC). Include provisions for an automatic, daily, weekly, 30 day, or up to 60 day communication link test from the PCU installation site to the SCC. Include a provision for displaying the internal system power and wiring conditions.

Include the following for internal monitoring points:

- a. The bell circuit

- b. AC power
- c. Battery voltage level
- d. Charging voltage
- e. Panel box tamper
- f. Phone trouble line 1
- g. Phone trouble line 2
- h. Transmit trouble
- i. Network trouble

A battery test must be automatically performed to test the integrity of the standby battery by disconnecting the standby battery from the charging circuit and placing a load on the battery. Perform this test at an interval no greater than 180 days.

#### 2.3.7 Detection Sensors

- a. Sensors are to detect facility perimeter or protected zone penetrations by unauthorized personnel or intruders and transmit an alarm signal to the alarm annunciation system upon change detection. Accomplish this with a probability of detection (PD) of 0.9 with a 95 percent confidence level and conforming to UL 639 where applicable.
- b. Required sensor power is 12 VDC unless otherwise specified.
- c. An interior IDS zone is a room or space within a building that can be secured and accessed independently from all other zones.
- d. Provide line supervision for all sensors with an end-of-line resistor at the sensor or within a tampered junction box with conduit from the junction box to the sensor.
- d. Provide sensors and components rated for operation in the installed environment. The sensors must transmit an alarm signal to the alarm annunciation system upon change detection. Provide all sensors with a tamper switch and elements housed in a tamper-alarmed enclosure in accordance of paragraph "Component Enclosure".

##### 2.3.7.1 Interior Sensors

###### 2.3.7.1.1 High Security Balanced Magnetic Switch (BMS)

Mount the BMS inside the secure location and on the opening side of the door. BMS sensors do not have the capability to incorporate an end-of-line (EOL) resistor.

###### 2.3.7.1.1.1 Level 1 Switch

UL 634. Level 1 High Security

###### 2.3.7.1.2 Passive Infrared Sensors

UL 639.

#### 2.3.7.2 Tamper Switches

- a. Corrosion-resistant tamper switches are required for the following IDS and CCTV equipment with hinged doors or removable covers that contain open circuits:
  - (1) Enclosures
  - (2) Cabinets
  - (3) Housings
  - (4) Boxes
  - (5) Raceways
  - (6) Fittings
  - (7) Sensors
- b. Tamper switches are to initiate an alarm signal when the door or cover is moved as little as 1/4 inch from the normally closed position. Mechanically mount tamper switches to maximize defeat time when enclosure covers are opened or removed. One second is the minimum amount of time required to depress or defeat the tamper switch after opening or removing the cover. Enclosure and tamper switch must prevent direct line of sight to internal components and prevent switch or circuit tampering. Conceal mounting hardware so switch cannot be observed from enclosure exterior.
- c. Tamper switches on doors which are opened to make normal maintenance adjustments to the system and to service power supplies must have a maintenance position.

##### 2.3.7.2.1 Tamper Switch Performance Requirements

Tamper switches are to be:

- a. Inaccessible until switch is activated.
- b. Under electrical supervision at all times, irrespective of the protection mode in which the circuit is operating.
- c. Annunciated to be clearly distinguishable from intrusion detection alarms and exempt from being disarmed, shunted, or silenced.
- d. Spring-loaded and held in the closed position by the door, or cover protected.
- e. Wired to break the circuit when the door or cover is disturbed.
- f. Wired so that each sensor and device is annunciated individually at the central reporting processor.

#### 2.4 ACCESS CONTROL SYSTEM (ACS)

Provide an access control system based upon a modular distributed microprocessor architecture complete with access control cards and ready

for operation.

- a. The ACS card credentials are required to be Common Access Cards (CAC), and CAC cards are being provided by the Government. Interface system with and provide alarm and other status to the overall ESS. Provide ACS that meets the communications requirements of UL 1076 and UL 294 and has the capability of controlling up to 4 card readers and keypads per card reader controller, 512 alarm inputs, or 512 relay outputs or any components combination.
- b. System is to grant or deny access or exit based upon:
  - (1) Keypad identification data
  - (2) CAC and PIV card identification data
  - (3) Time of day, day of week, and special day and holiday scheduling with card validation override.
- c. Decision to grant or deny access or exit is to be based upon authorization for such data to be input at a specific location for the current time period. Access decisions for high security areas are to be based upon two identification technology combinations: card and keypad .
- d. Provide ACS that supports the configuration and simultaneous monitoring of multiple access control devices when TCP/IP communication interfaces are used between the ESS and the primary Access Control Unit (ACU). The events of the ACS are to be viewable as separate or as a combined list of all ESS events. Provide overall control of the ACS, alarm monitoring, and photo identification through software control of the ESS.
- e. Access control, photo imaging, and programming data must reside on a single database and instantly accessible to every networked PC workstation connected to the ESS.
- f. Provide both supervised and non-supervised alarm point monitoring.
- g. Provide the capability to arm or disarm alarm points both manually and automatically by time of day, day of week or by operator command and the capability to disarm alarm points based on a valid access event.
- h. Provide programmable 'delay' setting for all alarm points. The alarm points are not to report an ENTRY type alarm until the delay setting has expired and not report a dwell type alarm condition until the alarm has been active for the full delay period.
- i. Provide the capability to place ACU(s) in an off-line mode. In the off-line mode, the ACU(s) must retain a historical summary of all ACU activity transactions, up to the maximum capacity of the ACU memory buffer. Provide the ability for manual operator control of system output relays with the manual functions to energize, de-energize, enable or disable.

#### 2.4.1 ACS Programming

Provide software capable of, but not limited to, the following programming:

#### 2.4.1.1 Time Schedules

Provide up to 256 user-definable time schedules. These time schedules are to determine the day(s) and times that access will be granted or a scheduled event is to occur. Any and all of the time schedules are to be available for defining access privileges and scheduled events. Provide ALWAYS and NEVER schedules that cannot be altered or removed from the system. Each user-defined time schedule must have the option of reacting or not reacting to user-defined special days, with the ability to react uniquely to each type of special day.

#### 2.4.1.2 Special Days

Provide an unlimited number of user definable special days to be used for configuring exceptions to the normal operating rules, typically for specifying holiday operating rules. Allow for each special day to be assigned to a user-defined type.

#### 2.4.1.3 ACU Daylight Savings Time Adjustment

Provide a software-configurable, user defined adjustment for Daylight Savings Time. The ACU must not need to be connected to a PC workstation in order for the adjustment to occur.

#### 2.4.1.4 Scheduled Events

Any access controlled reader is to be capable of scheduled unlock periods to allow for card-free access. The access controlled reader is to also be capable of requiring one valid access event before beginning a scheduled unlock period.

Any access control point is to be capable of requiring a valid card as well as a PIN code via keypad on a scheduled basis for high security areas. The use of PIN via keypad functions must not reduce the number of card readers or alarm points available in the ACU(s). Any designated alarm input must be able to be scheduled Secured and Accessed. Any relay output must be capable of scheduled ON and OFF periods to allow for automatic input and output system control.

#### 2.4.1.5 Maximum User Capability

Up to 64,000 individual users may be given access cards or codes and have their access controlled and recorded.

#### 2.4.1.6 Access Groups

Each system user must be assignable to a maximum of 256 possible access groups. An access group is defined as one or more people who are allowed access to the same areas at the same days and time periods.

#### 2.4.1.7 Active and Expire Dates

Any card or user may be configured with activation and expiration dates. The card can be assigned to any valid access group and will be activated and expired according to the specified dates.

#### 2.4.1.8 Maximum Use Settings

Any card or user may be configured with maximum number of uses for that



card. The card can be assigned to any valid access group and will be expired according to the specified number of card uses.

#### 2.4.1.9 Door Outputs

Provide each access control reader with two dedicated relay outputs. Both relays are to provide Normally Open and Normally Closed contacts. Use the first relay for electric lock control while the second is software configurable to activate for door forced open, door left open too long, duress, passback violations, invalid access attempts and valid unlock conditions. Allow for both relays to be separately programmable for energize times from 1 second to 10 minutes. The second relay must allow a delay time to be specified, causing its activation to be delayed after an activating condition occurs.

#### 2.4.1.10 Crisis Mode

Provide support for a "crisis mode", in which user-selected alarm point activations cause changes to user access privileges. The changes to user access privileges must be configurable to restrict normal access to no access or limited access.

#### 2.4.1.11 Door Groups

Allow up to 256 door groups to be configured. Doors belonging to the same group are to be able to be locked, unlocked, disabled, and enabled on command from the ACS.

#### 2.4.1.12 Door Interlocking

Allow a group of doors to be software configured so that if any door in the group is unsecure, all other doors are automatically disabled. This feature is also known as a "mantrap" configuration. The interlocking features must not require the ACS to be on-line for proper operation.

#### 2.4.1.13 PIN Required

Provide support for the required use of a keypad code, in addition to a valid credential during user-selected schedules.

#### 2.4.1.14 Remote Door Control

Provide the ESS operator the capability of manually controlling any access point by issuing a simple command from the ACS. Provide the operator the ability to lock, unlock, enable, and disable any door or Door Group in this manner. This activity is to cause an entry to be logged displaying the door name, number and time that it was performed.

#### 2.4.1.15 Key Control

When interfaced with an approved key-control system, the system is to allow users to deny access to certain doors for any users who have keys in their possession.

#### 2.4.1.16 Guard Tour

Provide support for user-defined guard tours configurable in a set pattern of tour points, or following a mode in which all tour points can be visited in any order within an allotted time. Allow for a tour to be

started by ACS command, by use of a selected card at a selected reader, or by use of a selected keypad code at a selected keypad. Detect guard late-to-point, point missed, and point out-of-sequence events. Generate a report at tour completion.

#### 2.4.1.17 Reader Disable

Provide support for disabling readers in reaction to a user-selected number of invalid access attempts. Locate a camera to view the card reader and interface to record the events of invalid access attempts.

#### 2.4.1.18 Disable Event Messages

Allow users to disable user-selected event messages (Door Forced Open, Door Open Too Long, Door Closed, Request to Exit) for user-selected doors. Allow users to disable certain messages (Door Forced Open, Door Open Too Long) according to a user-selected schedule.

#### 2.4.1.19 Input and Output Groups

Allow for up to 256 user-defined (input and output) groups to be defined. Each Input device is to be able to be linked to these groups for arming, disarming, shunting and unshunting as well as output control.

#### 2.4.1.20 Delays

Each alarm device must allow a delay to be specified which is either an entry type or a dwell type. An entry-type delay is to prevent the input from issuing an alarm event until the delay elapses. If unarmed during the delay period, the alarm is to be ignored. A dwell-type delay requires the input to remain in the alarm state for the full delay duration before issuing an alarm.

#### 2.4.1.21 Output Configuration

Allow each output relay to be software configurable as:

- (1) Follows
- (2) Latch
- (3) Timeout
- (4) Scheduled
- (5) Timeout Re-triggerable
- (6) Limit
- (7) Counter

Allow for a time schedule to automatically control the activation and de-activation of the Scheduled type with all other types configured to activate based on input and output group conditions. Additionally, a time schedule must be specified to configure when the output is to actively monitor the input and output groups.

#### 2.4.1.22 Remote Output Control

Provide the operator the capability of manually controlling any output point by issuing a simple command from the SCC. Based upon the output type, provide the ESS operator the ability to ENABLE, DISABLE, turn ON and turn OFF any output in this manner. A FOLLOWS type output must not be capable of being turned OFF or ON. Log an entry when this activity is performed displaying the output name and time performed. Manual control of outputs are not permissible in ICS 705-1 applications.

#### 2.4.1.23 Remote Reset Command

Provide the capability for any ACU to reset manually or by command issued from the ACS with the option of simulating the ACU reset settings, or forcing a reset type as specified by the user. The remote reset command is not to cause the ACU to degrade its level of protection to any access points defined.

#### 2.4.1.24 Time Zone

Allow the user to select the time zone in which the ACU is located, so that event times displayed for that ACU will match the local time where the ACU is located.

#### 2.4.1.25 User-Selected LED Behavior

Allow the user to select different behaviors for the LEDs of each access controlled reader.

#### 2.4.1.26 Traced Cards

Provide the capability of selecting any number of cardholders for the purpose of limiting reports to only traced users displaying all traced cardholder events in a user-selected alternate color.

#### 2.4.1.27 Badge Print Tracking

Support setting a print limit for any badge. The software will track the number of times any badge has been printed, as well as display the date and time of the most recent printing.

#### 2.4.2 Error and Throughput Rates

Rates must be portal to portal performance averages obtained when processing individuals one at a time. Features are not to reduce capability to meet throughput requirements when serial verification techniques or multiple attempts are required to satisfy error performance requirements.

A Type I error denies access to an authorized enrolled individual. A Type II error grants access to an unauthorized individual. Subsystem Type I and Type II error rates must both be less than .1 percent. At the error rates, subsystem access throughput rate must be minimum of 12 individuals per minute through one card reader and keypad access control device.

#### 2.4.3 Access Control System Central Processing

- a. Provide serial management and control of system processing. Provide a microprocessor control device able to monitor and control units and up

to 32 card reader and keypad access control devices. Central processor must interrogate and receive responses from each ACU within 100 milliseconds. Failure to respond to an interrogation is to cause an alarm.

- c. Provide enrollment equipment as required in paragraph ENROLLMENT CENTER EQUIPMENT.
- d. Provide system configuration controls and electronic diagnostic aids for subsystem setup and troubleshooting with the central processor. Components are not to be accessible to operations personnel and must be tamper alarmed.

#### 2.4.4 Access Control Unit(ACU)

UL 294. Provide micro-processor based ACU with all access and input and output decisions to be made by the individual ACU(s). Provide modular solution which will allow for present security requirements and the capability to expand. Configure all field ACU panels to intercommunicate via fiber-optic communication. Equip all field ACU(s) with a tamper contact.

Designate one ACU as "Primary", responsible for all ACS-to-ACU communications. All other ACU(s) up to a maximum of 256 are to be designated as "Secondary" and communicate with the "Primary" via an fiber-optic configuration. Provide ACU capable of, but not limited to, the following:

- a. Built-in surge suppression circuitry on plug-in modular circuit boards with surge suppression, configured as an integral component of the system and self-sacrificing in the event of extreme surges or spikes.
- b. Capable of supporting at least 2 ports and be expandable in increments of two ports up to a maximum of 16 ports per ACU.
- c. Each port configured by ACS to support any one of the following peripheral devices:

- (1) Card reader
- (2) Alarm Monitoring Module
- (3) Output Relay Module
- (4) Elevator Reader
- (5) Elevator Output Module

Any device combination can be supported on each ACU, up to a total of 16 devices per ACU.

- d. Capability of supporting multiple card reader technologies simultaneously, including:
  - (1) Keypad
  - (2) Card and Keypad

(3) CACorPIV compatible

This capability must be an integral part of the ACU and will not require special external equipment.

- e. Built-in battery back-up of programmed information sustainable for a period of at least 90 days.
- f. Powered by a 12 VDC power source rated at a minimum of 2 amperes with a battery back-up for complete system operation in the event of power failure. Provide battery backup for all ACU(s) to sufficiently power the ACU for 8 hours continuous service.
- g. Electric strikes, other locking devices and ancillary peripherals on a separate power supply with battery back-up for continued operation in the event of power failure as specified in paragraph "Backup Power".
- h. A minimum of a 10,300 event log buffer per ACU to record and hold access and alarm activity information until the ACS is connected and receives the information. Provide a software-configurable warning log buffer filling notification for ACU(s) configured with network switch capabilities.

#### 2.4.5 Access Control Devices

UL 294. The card, card reader, and panels must meet encryption requirements that are specified in paragraph DATA ENCRYPTION. Devices are to be tamper alarmed, tamper and vandal resistant, and solid state, containing no electronics which could compromise the access control subsystem should the subsystem be attacked.

##### 2.4.5.1 Card Readers

Provide surface card readers as indicated for each individual location. Provide and contactless type card readers capable of reading CAC, PIV and Keypad type of access control cards.

Keypads must contain an alphanumeric and special symbols keyboard with symbols arranged in ascending ASCII code ordinal sequence. Provide keypad as a stand-alone device or integrated into the card reader.

##### 2.4.5.1.1 Contact Card Readers

Provide contact card readers that can read credential PIV or CAC cards whose characteristics of size and technology meet those defined by ANSI ISO/IEC 7816 and are in compliance with NIST FIPS 201-2.

Provide readers with "flash" download capability to accommodate card format changes and the capability of reading the card data and transmitting the data, or a portion thereof, to the ESS control panel.

##### 2.4.5.1.2 Contactless Card Readers

Provide contactless card readers that can read credential PIV or CAC cards whose characteristics of size and technology meet those defined by ANSI ISO/IEC 7816 in close proximity to the card reader and are in

compliance with NIST FIPS 201-2.

Provide readers with "flash" download capability to accommodate card format changes and the capability of reading the card data and transmitting the data, or a portion thereof, to the ESS control panel.

#### 2.4.5.1.3 Card Reader Display

Provide card readers with an LED or other visual indicator display which indicate power ON and OFF and whether user passage requests have been accepted or rejected.

#### 2.4.5.1.4 Card Reader Response Time

The card reader is to respond to passage requests by generating a signal to the local processor.

#### 2.4.5.1.5 Card Reader Power

Power the card reader from the source as shown on the drawings. The card reader must not dissipate more than 5 Watts.

#### 2.4.5.1.6 Card Reader Mounting Method

Provide card readers suitable for surface or weatherproof mounting as required.

#### 2.4.5.2 Keypads

Entry control keypads are to use unique alphanumeric and other symbol combinations as an identifier. Keypads must contain an integral alphanumeric and special symbols keyboard with symbols arranged in ascending ASCII code ordinal sequence. Communications protocol is to be compatible with the local processor.

##### 2.4.5.2.1 Keypad Display

Keypads are to include an LED or other type of visual indicator display and provide visual status indications indicating power ON and OFF and whether user passage requests have been accepted or rejected.

The maximum horizontal and vertical viewing angles are to be limited by the keypad display or enclosure. The maximum horizontal viewing angle must be no more than plus and minus 5 degrees off a vertical plane perpendicular to the plane of the face of the keypad display. The maximum vertical viewing angle must be no more than plus and minus 15 degrees off a horizontal plane perpendicular to the plane of the face of the keypad display.

##### 2.4.5.2.2 Keypad Response Time

The keypad is to respond to passage requests by generating a signal to the local processor.

##### 2.4.5.2.3 Keypad Power

Power the keypad from the source as shown on the drawings. The keypad must not dissipate more than 5 Watts.

#### 2.4.5.2.4 Keypad Mounting Method

Provide keypads suitable for surface or weatherproof mounting as required.

#### 2.4.5.2.5 Keypad Duress Codes

Provide a means for users to indicate a duress situation by entering a special code into the keypad.

#### 2.4.5.3 Card Readers with Integral Keypad

Equip contact and contactless card readers with integral keypads as specified in paragraph "Keypads".

#### 2.4.5.4 Access Control Cards

Provide cards with the capability of modification and lamination during enrollment process without readability reduction for use as a picture and identification badge. Cards must contain binary coded data arranged in a scrambled pattern as a unique identification code stored on or within the card and of the type readable by the subsystem card readers. Include a non-duplicated unique facility access control subsystem identification code common to access control cards within the card binary data. Configure cards for use as a photo identification card suitable for lamination.

##### 2.4.5.4.1 Credential Card Modification

Provide entry control cards that can be modified by lamination or direct print process during the enrollment process for use as a picture and identification badge as needed for the site without readability reduction. Credential cards must allow adding at least one slot or hole for a clip affixing the credential card to the type badge holder used at the site.

##### 2.4.5.4.2 Warranty

Include a minimum 3-year warranty.

##### 2.4.5.5 Personal Identity Verification Equipment

Entry control personnel identity verification equipment must use a unique personal characteristic or unique personal physiological measurement to establish the identity of authorized, enrolled personnel. Provide a means to construct individual templates or profiles based upon measurements taken from the person to be enrolled. This template is to be stored as part of the System Reference Database Files. The stored template is to be used as a comparative base by the personnel identity verification equipment to generate appropriate signals to the associated local processors.

#### 2.5 CLOSED-CIRCUIT TELEVISION (CCTV) SYSTEM

Select system components that conform to the Open Network Video Interface Forum (ONVIF) specification. Provide compatible UL listed CCTV components to provide visual assessment of ESS alarms automatically upon alarm or upon SCC operator selection. Otherwise, the subsystem is to continuously display the coverage area. Display alphanumeric camera location ID on all monitors. Provide the number of alarm monitors as required. The scene

from each camera must appear clear, crisp, and stable on the respective monitor during both daytime and nighttime operation. Provide component equipment that minimizes both preventive and corrective maintenance. Provide components from a single manufacturer or justify mixing manufacturer components and demonstrate compatibility in submittal information.

#### 2.5.1 Cameras

##### 2.5.1.1 CCTV Camera

Provide cameras of digital fixed, pan-tilt-zoom (PTZ), or panoramic type as identified on the drawings.

- a. Day-Night fixed, PTZ or panoramic cameras are to be used in all outdoor environments. Standard fixed, PTZ, or panoramic cameras are to be used for all indoor applications except when backlighting issues are observed. Use Day-Night cameras or standard cameras with backlighting compensation for backlighting or high contrast applications.
- b. Provide PTZ cameras with a direct drive motor assembly. Belt driven PTZ camera units are not acceptable. Equip PTZ cameras with a slip ring assembly having an optical interface and be rated for continuous duty. PTZ cameras have to be fully integrated units. The pan-tilt mechanism must be an integral part of the camera.
- c. Provide cameras that operate over a voltage range of 24 VDC Power over Ethernet (PoE) IEEE 802.3.
- d. All cameras must be constructed to provide rigid support for electrical and optical systems so that unintentional changes in alignment or microphonic effects do not occur during operation, movement, or lens adjustments.
- e. Video Frame Rate: 30 frames per second (fps)
- f. Minimum essential requirements for cameras include the following:

##### 2.5.1.1.1 Sensitivity

Minimum Illumination: 0.08 foot-candles at F1.4 color mode; 0.01 foot-candles at F1.4 in the B&W mode.

##### 2.5.1.1.2 Signal-To-Noise Ratio

Show a signal-to-noise ratio of not less than 50 decibels (dB) at Automatic Gain Control (AGC) "Off", weight "On".

##### 2.5.1.1.3 Resolution

Provide a minimum of 2.1 megapixel resolution. The imager must have a minimum of 1920 horizontal x 1080 picture in progressive scan format. Resolution is to be maintained over the specified input voltage and frequency range, and not vary from minimum specification over the specified operating temperature range.



#### 2.5.1.1.4 Synchronization

Provide cameras that have internal and line lock.

#### 2.5.1.1.5 Low Light Level

Provide Day-Night cameras that have a B-W mode that may be automatically engaged on low light level and permit the use of an external infrared illuminator. Electronic removal of the color signal is not acceptable. The camera must have an infrared cut filter capable of being removed automatically upon low light threshold or manually.

#### 2.5.1.2 Camera Lenses

Camera lenses are to be all glass with coated optics. Provide lens mount that is C or CS mount, compatible with the cameras selected. Provide lens with the camera that have a maximum f-stop opening of f/1.2 or the maximum available for the focal length specified. The lens is to have an auto-iris mechanism unless otherwise specified. Lenses having auto iris, manual iris, or zoom and focus functions are to be supplied with connectors, wiring, receiver and driver units, and controls as needed to operate the lens functions. Provide lenses with sufficient circle of illumination to cover the image sensor evenly. Lenses are not to be used on a camera with an image format larger than the lens is configured to cover. Provide lens with focal lengths as indicated or specified in the manufacturer's lens selection tables.

#### 2.5.1.3 Camera Housing and Mounts

The camera and lens are to be enclosed in a tamper resistant housing installed on a camera support. Any ancillary housing mounting hardware needed to install the housing at the camera location is to be provided as part of the housing. The camera support must be capable of supporting the mounted equipment and withstanding wind and ice loads normally encountered at the site.

##### 2.5.1.3.1 Environmentally Sealed Camera Housing

The housing is to provide an environment needed for camera operation and be condensation free; dust and water tight; keep the viewing window free of fog, snow, and ice, and be fully operational in 100 percent condensing humidity. Provide housing equipped with a sunshield. Both the housing and sunshield are to be white. Purge the housing of atmospheric air and pressurized with dry nitrogen, equipped with a fill valve, overpressure valve, and include a humidity indicator visible from the exterior. Housing must not have a leak rate greater than 2 psi at sea level within a 90 day period.

Provide housing equipped with supplementary camera mounting blocks or supports needed to position the camera and lens to maintain the proper optical centerline. All electrical and signal connections required for camera and lens operation are to be supplied. Provide a mounting bracket as part of the housing which allows weight adjustment to center the weight of the assembly.

##### 2.5.1.3.2 Indoor Camera Housing

Provide housing with a tamper resistant enclosure for indoor camera operation and with the proper mounting brackets for the specified camera

and lens. The housing and appurtenances color are not to conflict with the building interior color scheme.

#### 2.5.1.3.3 Interior Mount

Provide camera mount suitable for either wall or ceiling mounting and have an adjustable head for mounting the camera. The wall mount and head must be constructed of aluminum or steel with a corrosion-resistant finish. Provide adjustable head with 360 degrees of pan and plus or minus 90 degrees of tilt.

#### 2.5.1.3.4 Low Profile Ceiling Mount

Provide tamperproof ceiling housing which is low profile and suitable for use in 2 by 2 foot ceiling tiles. The housing must be equipped with a camera mounting bracket and allows a 360 degree viewing setup.

#### 2.5.1.3.5 Exterior Dome Housing

Provide dome housing capable of being mounted by pendant, pole, ceiling, surface, or corner as shown on the drawings and constructed to be dust and water tight, and fully operational in 100 percent condensing humidity. Purge the housing of atmospheric air and pressurize with dry nitrogen. Provide a fill valve and overpressure valve with a pressure indicator visible from the exterior. The housing is to be equipped with supplementary camera mounting blocks or supports as needed to position the specified camera and lens to maintain the proper optical centerline.

Provide all electrical and signal connections required for camera and lens operation. The housing is to provide the environment needed for camera operation. The lower dome is to be black opaque acrylic with a light attenuation factor of not more than 1 f-stop. Provide housing with:

- a. Integral pan-tilt complete with wiring
- b. Wiring harnesses
- c. Connectors
- d. Receiver-driver
- e. Pan-tilt control system
- f. Pre-position cards
- g. Heavy duty bearings
- h. Hardened steel gears
- i. Permanent lubrication
- j. Motors that are thermally or impedance protected against overload damage.
- k. Any other hardware and equipment as needed to provide a fully functional pan-tilt dome. Provide pan movement of 360 degrees and tilt movement of at least plus or minus 90 degrees. Pan speed must be at least 20 degrees per second and tilt speed be at least 10 degrees per second.

#### 2.5.1.3.6 Exterior Wall Mount

Provide exterior camera wall mount that is 24 inches long, and has an adjustable head for mounting the camera. The wall mount and head must be constructed of aluminum, stainless steel, or steel with a corrosion-resistant finish. Provide adjustable head for at least plus and minus 90 degrees of pan, and at least plus and minus 45 degrees of tilt. If to be used in conjunction with a pan-tilt, provide bracket without the adjustable mounting head, and a bolt hole pattern to match the pan-tilt base.

#### 2.5.1.3.7 Pan-Tilt Mount

- a. Provide pan-tilt mount capable of supporting the camera, lens, and housing specified that is weatherproof and sized to accommodate the camera, lens and housing weight plus maximum wind loading encountered at the installation site if the pan-tilt is to be mounted outdoors. Provide pan-tilt with:
  - (1) Heavy duty bearings
  - (2) Hardened steel gears
  - (3) Externally adjustable limit stops for pan and tilt
  - (4) Mechanical, dynamic, or friction brakes
  - (5) Permanent lubrication
  - (6) Motors that are thermally or impedance protected against overload damage.
- b. Provide pan movement of 360 degrees pan rotation, a minimum tilt movement of plus and minus 90 degrees. Manual pan speed must be a minimum of 0 to 80 degrees per second , and a minimum tilt speed of 10 degrees per second . A minimum automatic pan speed of 280 degree per second and tilt speed of 160 degree per second.
- c. The pan-tilt is to be supplied complete with wiring, wiring harnesses, connectors, receiver-driver, pan-tilt control system, pre-position cards, or any other hardware and equipment as needed to provide a fully functional pan-tilt mount to fulfill the site design requirements.

#### 2.5.1.3.8 Explosion Proof Housing

The explosion proof housing must meet the requirements in paragraph "Component Enclosure" for hazardous locations. Configure housing to provide a tamper resistant enclosure and supply with the proper mounting brackets for the specified camera and lens.

#### 2.5.2 Thermal Imaging System

##### IP Thermal Cameras

- a. Provide an integrated thermal imaging device in an environmental enclosure.

- b. Provide a native digital image from the image sensor to the IP video stream.
- c. Provide of an uncooled, sun-safe amorphous silicon micro bolometer, long-wavelength infrared (LWIR) camera capable of 640 x 480 and 384 x 288 resolution formats.
- d. Provide a temporal Noise Equivalent Temperature Difference (NETD) below 50mK at f/1.0 capable of multiple display formats including white hot, black hot, and rainbow.
- e. Allow for input voltage of 24 VAC, 24 VDC, or a selectable power source of 120 VAC.
- f. Provide a built-in heater and defroster and sun shroud in accordance of paragraph "Component Enclosure".
- g. Support two simultaneous, configurable video streams. MJPEG and H.264 compression formats that are available for primary and secondary streams with selectable Unicast and Multicast protocols. The streams are to be configurable in a variety of frame rates, bit rates, and group of pictures (GOP) structures.
- h. Use a standard Web browser interface for remote administration and camera parameter configurations.
- i. Provide a 100Base-TX network port for live streaming to a standard Web browser.
- j. Provide built-in video analytics.

#### 2.5.3 Video Analytics (VA)

#### 2.5.4 Color Video Monitors

Except as specified, provide video monitors that:

- a. Are rated for continuous operation and incorporate printed circuit board modular construction.
- b. Have printed circuit modules that are easily replaceable.
- c. Use solid-state devices for electronic circuits.
- d. Are constructed to provide rigid support for electrical systems so that unintentional changes in alignment or microphonic effects will not occur during operation or movement.
- e. Incorporate circuit safety margins of not less than 25 percent where possible, with respect to power dissipation ratings, voltage ratings, and current carrying capacity.
- f. Have a diagonal viewing angle that nominally measures 24 inches for monitors, LED displays.
- g. Provide adequate safeguards to protect personnel from exposure to line voltage during operation or adjustment.
- h. Have at least the following essential requirements:

- (1) Resolution for LED monitors to be: 17 inch monitors - 1280x1024, 500 TV lines (maximum); 20.1 inch monitors - 1600x1200 (maximum)
- (2) Geometry: No point in the active raster is to deviate from its correct position by more than 2 percent of raster height.

#### 2.5.4.1 Mounting and Identification

- a. Mount monitors and other devices to facilitate easy replacement.
- b. The printed circuit board functions and component numbers or markings are to be easily read.
- c. Mount monitors in a desk top console.
- d. Protect monitors from circuit overloads by fuse or fuses in the power source line. Mount power source line fuses in finger-operated extractor fuse posts. Fuse holders are to be located in a readily accessible position.

#### 2.5.4.2 Video and Signal Input

Monitors are to operate with video input requiring a one HDMI or DVI nominal composite video signal switchable to either loop-through or internal 75-ohm terminating impedance.

Signal input connectors must be HDMI or DVI type.

#### 2.5.5 Ancillary Equipment

Equipment is to consist of the items specified below:

##### 2.5.5.1 Camera Identifiers

Label video signal from each camera using alphanumeric identifiers. Camera alphanumeric identifiers may originate from either the camera or the video recorder.

##### 2.5.5.2 Video Recording

#### 2.5.6 Camera Mounting Structures

Provide camera mounting structures designed specifically for CCTV cameras. The structure is to accommodate appropriate wiring pathways for power and communication as well as proper grounding and surge protection. Design loads for the camera mounting structure must conform to TIA-222 and all applicable addendums of the TIA standard. Allowable pole deflection is determined from the point of the camera mount and must not exceed 0.5 percent of the pole height under adjusted maximum wind load conditions. Adjusted maximum wind load conditions for deflection calculations must be 30 miles per hour (mph) or 35 percent of the basic wind speed as determined by TIA-222, whichever is greater. Confirm compliance to TIA standards by structure manufacturer data or by analysis. Provide additional measures as required to stabilize the camera if placed in an environment that is subject to induced vibrations such as heavy winds or excessive traffic.

## 2.6 COMMUNICATIONS

- a. Communications are to link together subsystems of the ESS and be in accordance with Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM. Interfaces between subsystems cannot be accomplished by use of an electro-mechanical relay assembly. Communications links must be supervised. Provide common communications interface devices throughout the ESS. Provide dry contact sensor to control unit interface that is normally OPEN or normally CLOSED, except as specified otherwise.
- b. Use digital, asynchronous, or multiplexed data control unit for central alarm reporting and display processor interface. Group individual data bits into word format and transmit as coded messages. Implement interface with network switches which function as a communications controller, perform data acquisition and distribution, buffering message handling, error checking, and signal regeneration as required to maintain communications.
- c. Provide totally automatic status changes communication, commands, field initiated interrupts, and any other communications required for proper system operation. Do not require system communication operator initiation or response. System communication is to return to normal after any partial or total network interruption including power loss or transient upset. Automatically annunciate communication failures to the operator with communication link identification that has experienced a partial or total failure.

### 2.6.1 Link Supervision

#### 2.6.1.1 Hardwire Direct Current Line Supervision

Provide only for the sensor to control unit links which are within the ESS protected area. Supervise circuits by monitoring changes in the current that flows through the detection circuit and a terminating resistor of at least 2.2 K ohms. Supervision circuitry is to initiate an alarm in response to opening, closing, shorting, or grounding of conductors by employing Class C standard line security. Class C circuit supervisor units are to provide an alarm response in the annunciator in not more than one second as a result of the following changes in normal transmission line current:

- a. Five percent or more in normal line signal when it consists of direct current from 0.5 through 30 milliamperes.
- b. Ten percent or more in normal line signal when it consists of direct current from 10 microamperes to 0.5 milliamperes.
- c. Five percent or more of an element or elements of a complex signal upon which security integrity of the system is dependent. This tolerance will be applied for frequencies up to 100 Hz.
- d. Fifteen percent or more of an element or elements of a complex signal upon which the security integrity of the system is dependent. This tolerance will be applicable for all frequencies above 100 Hz.

#### 2.6.1.2 Hardwire Alternating Current Supervision

Supervision is not to be capable of compromise by use of resistance,

voltage, or current substitution techniques. Use this method on circuits which employ a tone modulated frequency-shift keying (FSK), interrogate-and-reply communications method. Supervisory circuit are to be immune to transmission line noise, crosstalk, and transients. Terminate detection circuit by complex impedance. Maintain line supervision by monitoring current amplitude and phase. Size complex impedance so that current leads or lags the driving voltage by 45 plus or minus 5 degrees.

Alarm when rms current changes by more than 5 percent, or phase changes by more than 5 degrees for supervision current of 0.5 to 30 milliamperes rms. Alarm when rms current changes by more than 10 percent, or phase changes by more than 8 degrees for lines with supervision currents of 0.01 to 0.5 milliamperes. Identified line supervision alarm must be communicated within one second of the alarm.

#### 2.6.1.3 Hardwire Digital Supervision

Local processors are to exchange digital data to indicate secure or alarm at least every 2 seconds. Alarm if data is missed for more than one second for passive supervisory circuits. Coding used for data cannot be decipherable by merely viewing data on an oscilloscope. Supervisory circuits are to asynchronously transmit bursts of digital data for transponder schemes. Data pattern is to be random in nature. Remote detectors are to receive data and encode a response based on a proprietary coding scheme.

Provide a unique encoding scheme; Transmit encoded response back to supervisory circuit. Supervisory circuit is to compare the response to an anticipated response. Alarm on failure of the detector to return a data burst or return an incorrect response.

#### 2.6.2 Hardwire

##### 2.6.2.1 Electrical Conductor Lines

- a. Use electrical conductor lines for hardwire that rely on current path except for electrical wires; neutral conductors of electrical distribution systems cannot be used as signal transmitters.
- c. Ambient current levels chosen for line supervision must be sufficient to detect tampering and be within the normal operating range of electrical components. Report line supervision and tamper alarms regardless of mode of operation.
- d. Provide hardwire links as specified in UL 1076 and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM for interior applications with additions and modifications specified. Conductors are to be copper. Conductors for links which also carry AC voltage, are to be No. 12 AWG minimum; single conductors for low-voltage DC links are to be No. 14 AWG minimum. Conductors are to be color coded. Conceal wiring in finished areas of new construction and wherever practical in existing construction if not otherwise precluded by the Government.
- e. Identify conductors within each enclosure where a tap, splice, or termination is made. Identify conductors by plastic-coated, self-sticking, printed markers or by heat-shrink type sleeves.

Connect sensors, control units, and communication devices so that removal will cause a tamper alarm to sound. Pigtail or "T" tap connections are not acceptable. Each conductor used for identical functions is to be distinctively color-coded. Each circuit color-coded wire is to remain uniform throughout circuit. Tamper switches meet requirements of paragraph TAMPER SWITCHES.

2.6.2.2 Communication Link

- a. Provide a dedicated circuit communication link from sensor to control unit. Opening or closing a relay contact will indicate an alarm. Convert analog signals to digital values or a relay closure or opening within 250 feet of the sensing point. Communications from control unit to central alarm reporting and display processor are to operate in a continuous interrogation and response mode, using time-multiplexed digital communications techniques at a data rate of 10.24 kilobaud.
- b. Interrogation and response communications between the control unit and central processor is to be half-duplex and bidirectional on one dual twisted pair cable (one pair for interrogation and one for response), which may have one or more parallel branches. Individual control unit lines are to be at least 22 AWG wire. Connect control wires in parallel to the hardware link. Communication system is to provide as many as 255 control unit connections.
- c. The communication system must maintain specified performance over a link length of 7500 feet when operating without line repeaters or other signal regenerating or amplifying devices. The communications system must maintain specified performance over a link length of 75,000 feet when operating with signal-regenerating line repeaters.
- d. Control unit to central alarm reporting and display processor communications link is to also be capable of operating over a maximum of two standard voice grade telephone leased or proprietary lines. Link is to be capable of operating half duplex over a Type 3002 data transmission pair and be capable of modular expansion. Telephone lines will be provided by the Government. Coordinate and check out system operation. General characteristics and telephone line service are to be as follows:

Connections	Two- or four-wire
Impedance at 1000 Hz	600 ohms
Transmitting level	0 to 12 dBm
Transmitting level adjustment	3 dB increments
Type	Data
Direction	Two-way alternate (half duplex)
Maximum speed	10.24 kilobaud



Connections	Two- or four-wire
Maximum loss at 1000 Hz	33 dB

### 2.6.3 Video and ESS Transmission

Transmission is to be by optical fiber dedicated to the associated circuit. Video and ESS transmission cables must conform to the industry standards in Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM.

Install interior cable in Electrical Metallic Tubing (EMT) conduit unless indicated otherwise. Cable is to be rated for the installation method intended.

### 2.6.4 Wire and Cable

Provide all wire and cable not indicated as Government-furnished equipment. Wiring must meet NFPA 70 standards and as indicated in the Wire and Cable Data Sheets Attachment at the end of this section.

### 2.6.5 Digital Data Interconnection Wiring

Interconnecting cables carrying digital data between equipment located at the SCC or at a secondary control and monitoring site is to be optical fiber cable. Interconnecting cables conform to the industry standards in Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM .

### 2.6.6 Aboveground Sensor Wiring

Sensor wiring is to be 20 AWG minimum, twisted and shielded, 2, 3, 4, or 6 pairs to match hardware. Provide multiconductor wire with a PVC outer jacket.

### 2.6.7 Direct Burial Sensor Wiring

Sensor wiring is to be 20 AWG minimum, twisted and shielded, 2, 3, 4, or 6 pairs to match hardware.

### 2.6.8 Local Area Network (LAN) Cabling

Cabling must be in accordance with TIA-568-C.2, Category 6.

### 2.6.9 Cable Construction

Provide all cable components that will withstand the environment in which the cable is installed for a minimum of 20 years.

## 2.7 BACKUP POWER

- a. Intrusion alarms are not to be generated as a result of power switching; however, Provide a power switching indication and on-line source at the alarm monitor.
- b. The system is to automatically switch back to the primary source upon primary power restoration. Detect and report failure of an on-line battery as a fault condition. Power products must be in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

- c. Provide backup power to the primary power by backup batteries in each element or subsystem and uninterruptible power supply (UPS).

#### 2.7.1 Uninterruptible Power Supply (UPS)

Backup power required for uninterrupted ESS operation until a diesel engine generator set can assume the full load is to be provided by a UPS.

The UPS is to consist of a rectifier, battery and support racks, a static inverter, static switch transfer, and a manual bypass switch. Provide UPS with a continuous output to supply the maximum load requirements of the ESS. Size the battery to sustain the UPS at full rated load for 8 until diesel engine generator set can assume the load

#### 2.7.2 Batteries

Provide backup by dedicated batteries in remotely located system elements including individual sensors or control units. Batteries are to be an integral part of dispersed system elements when radio frequency (RF) operation is required. Batteries are to be capable of operation in any position and be protected against venting caustic chemicals or fumes within an equipment cabinet. Provide batteries capable of continuous operation for up to 24 hours without recharge or replacement.

#### 2.8 SURGE SUPPRESSION DEVICES

Comply with requirements in Section 33 82 00 TELECOMMUNICATION OUTSIDE PLANT (OSP).

#### 2.9 COMPONENT ENCLOSURE

Alarm enclosures with a tamper switch(es). Refer to paragraph "Tamper Switch". Enclosures is to be formed and assembled to be sturdy and rigid. These include:

- a. Consoles
- b. Annunciator housings
- c. Power supply enclosures
- d. Sensor control and terminal cabinets
- e. Control units
- f. Wiring gutters
- g. Other component housings

##### 2.9.1 Interior Sensor

Provide sensors to be used in an interior environment with a housing that provides protection against dust, falling dirt, and dripping noncorrosive liquids. Refer to paragraph "Interior Enclosures" for enclosure ratings.

##### 2.9.2 Exterior Sensor

Provide sensors to be used in an exterior environment with a housing that

provides protection against windblown dust, rain and splashing water, and hose directed water. Sensors are not to be damaged by the ice formation on the enclosure. Refer to paragraph "Exposed-to-Weather Enclosures" and "Corrosion-Resistant Enclosures" for enclosure ratings.

#### 2.9.3 Interior Enclosures

Enclosures to house equipment in an interior environment must meet the requirements of NEMA 250 Type 12.

#### 2.9.4 Exposed-to-Weather Enclosures

Enclosures to house equipment in an outdoor environment must meet the requirements of NEMA 250 Type 3R.

#### 2.9.5 Corrosion-Resistant Enclosures

Enclosures to house equipment in a corrosive environment must meet the requirements of NEMA 250 Type 4X.

#### 2.9.6 Hazardous Environment Equipment

All system electronics to be used in a hazardous environment must be housed in a metallic enclosure which meets the requirements of paragraph "Hazardous Locations."

#### 2.9.7 Metal Thickness

Thicknesses of metal in cast and sheet metal enclosures of all types must be not less than those listed in Tables 8.1, 8.2, and 8.3 of UL 1610 for alarm components, and NEMA ICS 2 and NEMA ICS 6 for other enclosures. Sheet steel used in enclosure fabrication is to be at least 16 gage; consoles are to be at least 18 gage.

#### 2.9.8 Doors and Covers

- a. Doors and covers are to be flanged. Provide tight pin hinges or the ends of hinge pins are to be tack welded to prevent ready removal where doors are mounted on hinges with exposed pins.
- b. Provide doors having a latch edge length of less than 24 inches with a single lock. Provide the door with a three-point latching device with lock where latch edge of a hinged door is 24 inches or more in length; or alternatively with two locks, one located near each end.
- c. The covers of provided junction boxes to facilitate initial system installation are to be held in place by tack welding, brazing, or one-way screws.

#### 2.9.9 Ventilation

Ventilation openings in enclosures and cabinets must conform to requirements of UL 1610.

#### 2.9.10 Mounting

Sheet metal enclosures are to be rated for wall mounting with top hole slotted, unless otherwise indicated. Mounting holes are to be in positions which remain accessible when major operating components are in

place and door is open, and be inaccessible when door is closed.

#### 2.9.11 Labels

Label boxes containing connections that they contain ESS connections and indicate that the box is part of the ESS system.

#### 2.9.12 Test Points

Provide readily visible and accessible with minimum disassembly of equipment to test points, controls, and other adjustments inside enclosures. Test points and other maintenance controls must be readily accessible to operator personnel.

### 2.10 EQUIPMENT RACK

Provide standard 19 inch electronic rack cabinets conforming to UL 50 for the ESS system at the SCC and remote control and monitoring sites as shown on the drawings. Equipment rack must be in accordance with Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM.

#### 2.10.1 Labels

Provide a labeling system for cabling as required by TIA-606 and UL 969. Provide stenciled lettering for voice and data circuits using laser printer.

### 2.11 FACTORY APPLIED FINISH

Electrical equipment is to have factory-applied painting systems which meet the requirements of the NEMA 250 corrosion-resistance test as a minimum.

## PART 3 EXECUTION

### 3.1 INSTALLATION

Install the system in accordance with safety and technical standards NFPA 70, UL 681, UL 1037, and UL 1076. Configure components within the system with appropriate service points to pinpoint system trouble in less than 20 minutes.

Install all system components, including any equipment that is furnished by the Government, and appurtenances in accordance with the manufacturer's instructions, IEEE C2 and as shown on the drawings, and furnish all necessary connectors, terminators, interconnections, services, and adjustments required for a complete and operable system.

#### 3.1.1 Existing Equipment

Connect to and utilize existing equipment, control signal transmission lines, and devices as shown on the drawings. Any equipment and signal lines that are usable in their original configuration without modification may be reused with Government approval.

Make written requests and obtain approval prior to disconnecting any signal lines and equipment that creates equipment outage. Such work can proceed only after receiving Government approval of these requests. If any device fails after work has commenced on that device, signal, or control line, diagnose the failure and perform any necessary corrections

to the equipment. The Government is responsible for maintenance and repair of Government equipment. The Contractor will be held responsible for repair costs due to negligence or abuse of Government equipment on their part.

### 3.1.2 Enclosure Penetrations

Enclosures are to be penetrated from the bottom unless shown otherwise. Penetrations of interior enclosures having transitions of conduit from interior to exterior, and penetrations of exterior enclosures are to be sealed with rubber silicone sealant to preclude the entry of water. Terminate conduit risers in a hot-dipped galvanized metal cable terminator that is filled with a sealant as recommended by the cable manufacturer, and in a manner that does not damage the cable.

### 3.1.3 Cable and Wire Runs

Perform required cable and wire routings per NFPA 70 and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM, and as specified. Terminate conduits including flexible metal and armored cable in the sensor or device enclosure. Fit ends of conduit with insulated bushings. Exposed conductors at ends of conduits external to sensors and devices are not acceptable.

### 3.1.4 Soldering

Soldered electrical connections must use composition Sn60, Type AR or S, for general purposes; use composition Sn62 or Sn63, Type AR or S, for special purposes. Flux must conform to ASTM B32 when Type S solder is used for soldering electrical connections.

### 3.1.5 Galvanizing

Ferrous metal is to be hot-dip galvanized in accordance with ASTM A123/A123M. Provide screws, bolts, nuts, and other fastenings and supports that are corrosion resistant.

Field welds or brazing on factory galvanized boxes, enclosures, conduits, and so on, are to be coated with a cold galvanized paint containing at least 95 percent zinc by weight.

### 3.1.6 Conduits

Install interior conduits in accordance with NFPA 70, Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and ICS 705-1. Install exterior conduits in accordance with NFPA 70, Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION and ICS 705-1.

## 3.2 ADJUSTMENT, ALIGNMENT, SYNCHRONIZATION, AND CLEANING

- a. Clean each system component of dust, dirt, grease, or oil incurred during and after installation or accrued subsequent to installation from other project activities subsequent to installation.
- b. Prepare for system activation by manufacturer's recommended procedures for adjustment, alignment, or synchronization.
- c. Prepare each component in accordance with appropriate provisions of component installation, operations, and maintenance manuals.

- d. Remove large vegetation that may sway in the wind and touch fencing.
- e. Adjust sensors so that coverage is maximized without mutual interference.

### 3.3 SYSTEM STARTUP

Do not apply power to the system until after:

- a. Set up system equipment items and communications in accordance with manufacturer's instructions.
- b. Conduct a system visual inspection to ensure that defective equipment items have not been installed and that there are no loose connections.
- c. Test and verify system wiring as correctly connected.
- d. Verify system grounding and transient protection systems as properly installed.
- e. Verify the correct voltage, phasing, and frequency of the system power supplies.

Satisfaction of the requirements above does not relieve the contractor of responsibility for incorrect installations, defective equipment items, or collateral damage as result of Contractor work or equipment.

### 3.4 SUPPLEMENTAL CONTRACTOR QUALITY CONTROL

Provide the services of technical representatives who are familiar with all components and installation procedures of the installed system; and are approved by the Contracting Officer. These representatives are to be present on the job site during the preparatory and initial phases of quality control to provide technical assistance. These representatives are also to be available on an as needed basis to provide assistance with follow-up phases of quality control. These technical representatives are to participate in the system testing and validation and provide certification that their respective system portions meet the contractual requirements.

The above requirements supplement the quality control requirements specified elsewhere in the contract.

-- 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 (2021) 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

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 13.00 14 WET PIPE SPRINKLER SYSTEM, FIRE PROTECTION  
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 4-010-06 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 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.

##### 1.4.5 Terminal Cabinet

A steel cabinet with locking, hinge-mounted door where terminal strips are securely mounted inside the cabinet.

#### 1.4.6 Control Module and Relay Module

Terms utilized to describe emergency control function interface devices as defined by NFPA 72.

#### 1.4.7 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.

#### 1.4.8 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  
Heat 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

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 FACU.
  - (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 FACU.
- 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 FA CU.

- 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 must be recessed mount; those located on concrete walls must 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 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) 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"
- (6) All Clear Message: "The emergency has now ended. Please resume normal operations. Thank you for your cooperation." Text Message: "ANNOUNCEMENT: "RESUME NORMAL OPERATIONS"
- (7) 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"
- (8) 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).

### 2.4 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.

### 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 AIR SAMPLING SMOKE DETECTION SYSTEM

The addressable air sampling smoke system must consist of a detector assembly housing an integral aspiration fan, filter, laser-based detection chamber and control, output and supervision circuitry. Each sampling point must be capable of being independently addressable. The system must consist of a piping or tubing distribution network that runs from the detector assembly(s) to the protected area(s) and is supported by air sampling smoke detection system calculations from a computer-based design modeling tool. The system must include configurable alarm and trouble relay outputs for interface to other systems where required.

- a. System must be complete in all ways. It must include all engineering, and electrical installation, all detection and control equipment, auxiliary devices and controls, alarm interface, functional checkout and testing, training and all other operations necessary for a functional system.
- b. System base detectors and modules must each accommodate up to 40 addressable microbore sampling tubes where each tube has a sampling point at the end. Additional modules may be used to provide up to 20 addressable sampling holes per system.
- c. Program alarm thresholds to the following values unless the results of

the pre-Government system tests indicate a clear need to change them. In the event that such a need is indicated, notify the Contracting Officer and provide complete documentation concerning the need to deviate from these values. Include within the deviation documentation request, information that complies with the paragraph entitled "Sensitivity Verification Test". Ensure initial threshold levels are approved prior to the Government test.

- (1) Alarm Level 1: set ALERT at 0.0250 percent obscuration/foot
  - (2) Alarm Level 2: set PRE-ALARM at 0.0500 percent obscuration/foot
  - (3) Alarm Level 3: set FIRE 1 at 0.1000 percent obscuration/foot
  - (4) Alarm Level 4: set FIRE 2 at 0.2000 percent obscuration/foot
- d. All air sampling smoke detection devices and associated components must be new, standard products or the manufacturer's latest design and suitable to perform the functions intended.
- e. The laser detection chamber must be of the mass light scattering type and capable of detecting a wide range of smoke particle types of varying size. A particle counting method must be employed for the purposes of:
- (1) Preventing large particles from affecting the true smoke reading.
  - (2) Monitoring contamination of the filter (for example, dust and dirt) to automatically notify when maintenance is required. The particle counting method must not be used for the purpose of smoke density measurement.
- f. Detector(s) must be self-monitoring for filter contamination and provide indication through system fault when replacement is necessary. Detectors which allow automatic reset of filter status upon removal and re-insertion are not permitted.
- g. Detector(s) must contain relays for alarm and fault conditions. The relays must be software programmable to the required functions.
- h. Detector(s) must permit configuration by programmers that are either integral to the system, portable or PC based.
- i. Detector(s) must allow programming of:
- (1) Smoke threshold alarm levels; ALERT, PRE-ALARM, FIRE 1 and FIRE 2.
  - (2) Time delays. Ensure the display control unit contains individual adjustable alarm time delay features for each of the alarm threshold levels. Provide an adjustment range between 0 and 60 seconds. Program the alarm threshold time delays to 30 seconds for alarm levels 1 and 2, and 15 seconds for alarm levels 3 and 4.
  - (3) Faults, including airflow, detector, power, filter and network, as well as an indication of the urgency of the fault.
  - (4) Configuration of relay outputs for remote indication of alarm and fault conditions.

(5) General purpose input functionality.

## 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 on the exterior must be rated for wet locations, NEMA 4 or 3R, 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.

#### 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.

#### 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.

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.

## 2.18 AUTOMATIC FIRE ALARM TRANSMITTERS

### 2.18.1 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.

#### 2.18.1.1 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.

#### 2.18.1.2 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.

#### 2.18.1.3 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.

#### 2.18.1.4 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.

### 2.18.2 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
- f. Heat detectors

Sprinkler valve supervision

Mass Notification System activated

As shown on the system matrix

## 2.19 SYSTEM MONITORING

### 2.19.1 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.

### 2.19.2 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.

## 2.20 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.

### 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.

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 must be performed by the approved firestopping installer specified in 07 84 00, per approved designs and fire stop shop drawings with penetrating items, F and T ratings, UL designs and their locations.

### 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)

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## 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)

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- 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)

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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  
(600 kN-m/cu. m.))

ASTM D1140 (2017) Standard Test Methods for  
Determining the Amount of Material Finer  
than 75-um (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/ft<sup>3</sup>) (2700 kN-m/m<sup>3</sup>)

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

Also refer to the Joint Base San Antonio (JBSA) specific Section 01 57 20 ENVIRONMENTAL PROTECTION as well as the JBSA Soil Management Plan attached as an appendix.

## 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 Sheet piling

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 sheet piling 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.

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) One test per 50 linear feet of footing. One test per 500 SF within building line
(2) Fills & Backfills	(2) Structures		(3) One test per 500 square feet.  (4) One test per 1000 SF  (5) One test per lift per 250 cubic yards
(3) Subgrades	(3) Airfield		
(4) Subgrades	(4) Site		Double testing frequency for areas compacted by hand-operated machines.
(5) Embankments or Borrow	(5) All		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 05 21

GEOGRID SOIL REINFORCEMENT  
08/08

PART 1 GENERAL

1.1 MEASUREMENT AND PAYMENT

The unit of measurement for soil reinforcement will be square yards (SY). Overlaps for splices (if allowed) and for the Contractor's convenience will not be measured for payment. Payment will be made at the respective unit price listed on the bidding schedule. Payment will be full compensation for furnishing all material, labor, equipment, supplies and incidentals to complete the 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.

ASTM INTERNATIONAL (ASTM)

ASTM D4873/D4873M (2017) Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples

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

Installation; G

SD-03 Product Data

Manufacturer

SD-04 Samples

Geogrid Reinforcement

SD-06 Test Reports

Geogrid Reinforcement  
Splices

1.4 QUALITY ASSURANCE

Submit a summary of the manufacturer's qualifications and 3 copies of the

manufacturer's quality control (QC) manual a minimum of 7 days prior to delivery of geogrid to the site. The reinforcement manufacturer shall provide a qualified and experienced representative to be available on an as-needed basis during construction. The representative shall visit the site for consultation as requested by the Contracting Officer.

### 1.5 DELIVERY, STORAGE, AND HANDLING

Check products upon delivery to ensure that the proper material has been received and is dry and undamaged. Protect the materials from damage and exposure following the guidelines presented in ASTM D4873/D4873M.

#### 1.5.1 Labeling

Label each roll with the manufacturer's name, product identification, roll dimensions, lot number, and date manufactured.

#### 1.5.2 Handling

Handle and unload geogrid rolls by hand, or with load carrying straps, a forklift with a stinger bar, or an axial bar assembly. Geosynthetic rolls shall not be dragged, lifted by one end, lifted by cables or chains, or dropped to the ground.

#### 1.5.3 Storage

Protect geogrid from deleterious materials, chemicals, sparks and flames, temperatures in excess of 160 degrees F, and any other environmental condition that may degrade the physical properties. If stored outdoors, the rolls shall be elevated from the ground surface. Protect geogrids, except for extruded grids, with an opaque waterproof cover.

## PART 2 PRODUCTS

### 2.1 GEOGRID REINFORCEMENT

The geogrid shall be manufactured from a punched polypropylene sheet with triangular apertures with equilateral sides forming a molecular orientation. The properties of the grid fabric shall be as follows:

Index Properties	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 SPLICES

Splices shall consist of a standard method or device recommended by the manufacturer of the geogrid.

PART 3 EXECUTION

3.1 INSTALLATION

Submit Geogrid layout plan along with anchorage and joint details, sequencing and construction procedures, a minimum of 7 days prior to geogrid placement.

3.1.1 Subgrade Preparation

Immediately prior to placement of the geogrid, the surface on which the geogrid will be placed shall be free of rock and other material that could damage the geogrid or the underlying geosynthetics.

3.1.2 Placement

Install the geogrid in accordance with the Manufacturer's recommendations. Unroll the geogrid in the direction of reinforcement. After a layer of geogrid has been placed, use suitable means, that do not damage the underlying geosynthetics, to hold the geogrid flat and in place until cover soil can be placed. Geogrid damaged during placement and covering shall be removed and replaced at no additional cost to the Government.

3.1.3 Overlaps and Fasteners

Overlaps and fastening shall be per manufacturer recommendations.

3.1.4 Splices

Splices shall be per manufacturer recommendations.

-- 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 31 63 29

DRILLED CONCRETE PIERS AND SHAFTS

11/19

PART 1 GENERAL

1.1 UNIT PRICES

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 CONCRETE INSTITUTE (ACI)

ACI 117	(2010; R 2015) Specifications for Tolerances for Concrete Construction and Materials and Commentary
ACI 301	(2020) Specifications for Structural Concrete
ACI 304R	(2000; R 2009) Guide for Measuring, Mixing, Transporting, and Placing Concrete
ACI 305R	(2020) Guide to Hot Weather Concreting
ACI 306.1	(1990; R 2002) Standard Specification for Cold Weather Concreting
ACI 318	(2019; R 2022) Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)
ACI 336.1	(2001) Specification for the Construction of Drilled Piers
ACI SP-66	(2004) ACI Detailing Manual

AMERICAN WELDING SOCIETY (AWS)

AWS A5.1/A5.1M	(2012) Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
AWS D1.1/D1.1M	(2020; Errata 1 2021) Structural Welding Code - Steel
AWS D1.4/D1.4M	(2018) Structural Welding Code - Reinforcing Steel

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 (2023) Standard Practice for Making and  
Curing Concrete Test Specimens in the Field

ASTM C39/C39M (2023) Standard Test Method for  
Compressive Strength of Cylindrical  
Concrete Specimens

ASTM C94/C94M (2023) Standard Specification for  
Ready-Mixed Concrete

ASTM C143/C143M (2020) Standard Test Method for Slump of  
Hydraulic-Cement Concrete

ASTM C150/C150M (2022) Standard Specification for Portland  
Cement

ASTM C172 (2010) Standard Practice for Sampling  
Freshly Mixed Concrete

CONCRETE REINFORCING STEEL INSTITUTE (CRSI)

CRSI 10MSP (2018; Errata 2019) Manual of Standard  
Practice

U.S. FEDERAL HIGHWAY ADMINISTRATION (FHWA)

FHWA NHI-10-016 (2010) Drilled Shafts: Construction  
Procedures and LRFD Design Methods

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

29 CFR 1926.651 Specific Excavation Requirements

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-01 Preconstruction Submittals

Installation Plan

SD-02 Shop Drawings

SD-05 Design Data

SD-06 Test Reports

Soils Report; G

Ground Water Conditions

Load Test; G

Penetration Test; G

Slump

Concrete; G

Compressive Strength; G

SD-07 Certificates

Steel Reinforcement; G

Welding Certificates; G

Excavation and Drilling Equipment

Qualifications of Excavator; G

#### 1.4 QUALITY CONTROL

##### 1.4.1 General

Install drilled shaft foundations in accordance with applicable requirements as described by ACI 336.1, and FHWA NHI-10-016.

##### 1.4.2 Sequencing and Scheduling

Submit a detailed installation plan describing the schedule for drilling and/or excavation, installation of steel reinforcement and concrete placement with anticipated site conditions so that each excavated shaft is poured the same day that the drilling is performed.

##### 1.4.3 Inspection Criteria

Design inspection activities to minimize delays while insuring the intent of the Industry Standard Specifications.

##### 1.4.4 Qualification of Excavation Contractor

An experienced excavator with five (5) years experience and licensed in the State of Texas, specialized in excavating and installing work similar in material, design, and extent to that indicated for this Project. Submit certificates substantiating the Qualifications of Excavator.

##### 1.4.5 Welding Qualifications

Provide and maintain qualified procedures and personnel according to AWS D1.1/D1.1M, AWS D1.4/D1.4M, and AWS A5.1/A5.1M. Submit Welding Certificates to the Contracting Officer.

#### 1.4.6 Pre-Construction Conference

After submittals are received and approved but before drilled shaft excavation and foundation work, including associated work, is performed, the Contracting Officer will hold a pre-construction conference to review the following:

- a. The drawings, specifications and the geotechnical report.
- b. Finalize construction schedule and verify availability of materials, Excavator's personnel, equipment, and facilities needed to make progress and avoid delays.
- c. Methods and procedures related to drilled shaft foundation installation, including engineer's written instructions.
- d. Support conditions for compliance with requirements, including alignment between foundation system and erection of structural members.
- e. Governing regulations and requirements for, certificates, insurance, tests and inspections if applicable.
- f. Temporary protection requirements for foundation assembly during and after installation.

#### 1.5 PROJECT CONDITIONS

##### 1.5.1 Existing Conditions

Locate existing underground utilities before excavating drilled shaft foundations. If existing utilities are to remain in place, provide protection during drilled shaft operations.

##### 1.5.2 Interruption of Existing Utilities

Do not interrupt any utility to occupied facilities unless directed in writing by the Contracting Officer.

##### 1.5.3 Weather Limitations

Proceed with installation preparation only when existing and forecasted weather conditions permit work to proceed without water entering into the area of excavation.

#### PART 2 PRODUCTS

##### 2.1 EQUIPMENT

###### 2.1.1 Drilling and Excavation Equipment

Provide drilling and excavation equipment having adequate capacity, including but not limited to, power, torque and down thrust to excavate a hole of diameter and depth indicated. Also provide excavation and over-reaming tools of adequate design, size and strength to perform the work indicated.

Provide special drilling equipment including, but not limited to, rock core barrels, rock tools, air tools and other equipment as necessary to construct the shaft excavation to the size and depth indicated when

materials encountered can not be drilled using earth augers and/or over-reaming tools.

Submit certificates substantiating appropriate selection of excavation and drilling equipment.

## 2.2 MATERIALS

### 2.2.1 Steel Reinforcement

#### 2.2.1.1 Deformed Steel Bars

Steel bars conforming to ASTM A615/A615M, Grade 60 ksi and ACI 318.

#### 2.2.1.2 Plain Steel Wire

Steel wire conforming to ASTM A1064/A1064M.

### 2.2.2 Ready-Mix Concrete

Ready-Mix concrete and mix design conforming to ACI 117, ACI 301, and ACI 304R, minimum compressive strength 5,500 psi at 28 days. Slump results between 5 to 6 inches, according to ASTM C143/C143M.

Portland cements conforming to ASTM C150/C150M, Type II. Provide one brand and type of cement for formed concrete having exposed-to-view finished surfaces.

Potable water conforming to ASTM C94/C94M.

Measure, batch, mix and deliver concrete according to ASTM C94/C94M and furnish batch ticket information.

## PART 3 EXECUTION

### 3.1 PREPARATION

Protect existing structures, utilities, sidewalks, pavements, and other facilities from damage caused by settlement, lateral movement, vibration, and other hazards created by drilled shaft foundation operations.

Provide Fall Protection as required by Section 01 35 26 GOVERNMENTAL SAFETY REQUIREMENTS and 29 CFR 1926.651.

### 3.2 INSTALLATION

#### 3.2.1 Construction Criteria

Provide equipment for checking the dimensions and alignment of each shaft excavation. Determine dimensions and alignment jointly with the contractor and engineer. Measure final shaft depths with appropriate weighted tape measure or other approved method after cleaning.

Provide and install monolithically cast-in-place concrete drilled shaft foundation to the sizes indicated.

Provide and install straight cylindrical shaft w/belled bottom as indicated in the contract drawings foundation of the type indicated.



Tolerances:

- a. Maximum variation of the center of any shaft foundation from the required location: 3 inches, measured at the ground surface.
- b. Bottom Diameter: Minus zero, plus 6 inches, measured in any direction.
- c. Maximum variation from plumb: 1:40.
- d. Maximum bottom level: Plus or minus 2 inches.

### 3.2.2 Excavation

Accomplish excavation of shaft foundations by standard excavation methods including, but not limited to, conventional augers fitted with soil and/or rock teeth, or under-reaming tools attached to drilling equipment of adequate size, power, torque and down thrust necessary for the work.

Perform excavation through whatever materials that are encountered to the dimensions, depths and applicable ACI 336.1 tolerances.

Protect excavated walls with temporary watertight steel casings of sufficient length to prevent water intrusion, cave-ins, displacement of surrounding earth, and injury to personnel and damage to construction operations.

Excavate shafts for drilled foundations to indicated elevations. Remove loose debris, materials and/or muck to make bottom surfaces level within ACI 336.1 tolerances.

Remove water from excavated shaft prior to concrete placement.

### 3.2.3 Steel Reinforcement

Comply with recommendations in the CRSI "Manual of Standard Practice" CRSI 10MSP for fabricating, placing and supporting reinforcement. Shop fabricate steel reinforcement in accordance with ACI SP-66.

When practicable, deliver the reinforcement cage assembly to the jobsite as a complete unit ready for installation. Should it be necessary to make any additional connections and/or splices, provide as indicated on the approved shop drawings, at-grade level prior to lowering the complete assembly into the hole.

Clean reinforcement of loose rust, mill scale, earth and other foreign materials. Do not tack weld crossing reinforcing bars. Set wire ties with ends directed into concrete, not toward exposed concrete surfaces.

Lower reinforcement steel into the hole in such a manner as to prevent damage to the walls of the excavation. Place, tie and/or clip cage symmetrically about the axis of the shaft. Use centering devices securely attached to the cage to clear the shaft walls and maintain the cage in place throughout the concrete placement operations.

Cooperate with other trades in setting of anchor bolts, inserts, and other embedded items. Where conflicts occur between reinforcing and embedded items, notify the Contracting Officer in order to reconcile conflicts before concrete placement. Position and support anchors and embedded items with appropriate accessories.

Use templates to set anchor bolts, leveling plates and other accessories required for structure erection. Provide blocking and/or holding devices to maintain required anchoring positions during final concrete placement.

#### 3.2.4 Concrete Placement

Keep all equipment, including but not limited to, mixers, pumps, hoses, tools and screeds clean and free of set concrete throughout the placement operation.

Convey concrete from the mixer to place of deposit by best industry methods that prevents segregation and loss of material. Size and design the equipment for conveying concrete to ensure uniform, continuous placement of concrete.

Place concrete in accordance with ACI 318.

Place concrete in a continuous operation and without segregation into dry excavations whenever possible after inspection and written approval by the Contracting Officer. Use all practicable means to obtain a dry excavation before and during concrete placement.

Protect freshly placed concrete from premature drying and excessive cold or hot temperatures. When hot weather conditions exist that would impair quality and strength of placed concrete, comply with ACI 305R. Comply with ACI 306.1 for cold-weather protection.

A minimum of 50 percent of the base for each shaft is to be less than 1/2 inch of sediment at the time of concrete placement. Maximum depth of sediment or debris at any place on the base of the shaft is not to exceed 1-1/2 inches. Shaft cleanliness is to be determined by the engineer by visual inspection.

### 3.3 FIELD QUALITY CONTROL

#### 3.3.1 Test Reports

As a minimum, submit the following test reports and data.

- a. Soils Report
- b. Ground Water conditions
- c. Load Test
- d. Penetration Test
- e. Slump
- f. Concrete
- g. Compressive Strength

Sample and test concrete for quality control during placement.

Sample freshly placed concrete for testing in accordance with ASTM C172.

Make concrete test specimens for compressive strength at 7 and 28 days for

each design mix conforming to ASTM C31/C31M. Compression test concrete in accordance with ASTM C39/C39M.

Test Slump at plant for each design mix in accordance with ASTM C143/C143M.

-- 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 SIDEWALK AND SUBBASE FOR FLEXIBLE PAVING  
**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 <sup>3</sup> ) (2700 kN-m/m <sup>3</sup> )
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

## 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.erd.c.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 subbase course and rigid pavement 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 sidewalk base course and subbase 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 1/4 inch
Average Job Thickness	Plus/Minus 1/4 inch
Compaction	
Subbase	Minimum 100 percent
Sidewalk	Minimum 95 percent

1.6.2 Test Section

A test section is not required.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Subbase 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 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 aggregate that is reasonably uniform in density and quality. Provide aggregates with a maximum size of 2 inch, a minimum of 70 percent passing the 3/4 inch sieve, and within the limits specified as follows:

Table 2	
Maximum Allowable Percentage by Weight Passing Square-Mesh Sieve	
Sieve Designation	No. 2
No. 10	80
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 5.

2.1.2 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
No. 200	15

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 6. 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 subbase or sidewalk base course. Do not construct subbase or 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 subbase or 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 1/2 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 1/4 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 subbase and sidewalk base course 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 subbase 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 PROOF ROLLING

Proof rolling is not required.

### 3.10 EDGES OF SUBBASE AND SIDEWALK BASE COURSE

Place approved material along the outer edges of the subbase and sidewalk pavement 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 subbase and sidewalk pavement base course, 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 subbase and sidewalk pavement 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 12 13

BITUMINOUS TACK AND PRIME COATS

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 D8	(2022a) Standard Terminology Relating to Materials for Roads and Pavements
ASTM D88/D88M	(2007; R 2009; E 2019) Standard Test Method for Saybolt Viscosity
ASTM D140/D140M	(2016) Standard Practice for Sampling Asphalt Materials
ASTM D977	(2020) Standard Specification for Emulsified Asphalt
ASTM D1250	(2019; E 2020) Standard Guide for Use of the Joint API and ASTM Adjunct for Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products, and Lubricating Oils: API MPMS Chapter 11.1
ASTM D2027/D2027M	(2019) Cutback Asphalt (Medium-Curing Type)
ASTM D2170/D2170M	(2018) Standard Test Method for Kinematic Viscosity of Asphalts (Bitumens)
ASTM D2397/D2397M	(2020) Standard Specification for Cationic Emulsified Asphalt
ASTM D2995	(2023) Determining Application Rate of Bituminous Distributors

1.2 DEFINITIONS

See ASTM D8 for more definitions relating to this specification.

1.2.1 Prime Coat

Application of a low-viscosity asphalt material to an absorptive surface, such as an unbound granular layer, designed to penetrate, bond, temporarily weatherproof, and stabilize this existing surface and to promote adhesion between it and construction course that follows.



#### 1.2.2 Tack Coat

Tack Coat is also referred to as bond coat. Tack coat is an application of bituminous material to an existing relatively nonabsorptive surface, such as existing densely graded asphalt mixture (milled or new), to provide a thorough bond between old and new surfacing.

#### 1.2.3 Emulsion

Emulsion is also known as emulsified asphalt or asphalt emulsion. Mostly made of paving grade asphalt binder and water containing a small amount of emulsifying agent. Emulsifying agent may also be referred to as a surfactant. The purpose of the surfactant is to prevent the coalescence of the asphalt droplets and to keep them suspended independently in the water. Surfactants used in the emulsions can be produced with positive or negative charges resulting in anionic or cationic emulsions.

#### 1.2.4 Diluted Emulsion

An emulsion that has been diluted by adding an additional amount of water equal to or less than the total volume of emulsion.

#### 1.2.5 Residual Asphalt

The amount of asphalt binder remaining after all water has evaporated from an asphalt emulsion.

#### 1.2.6 Shot Rate

Shot rate, also referred to as bar rate, is the application rate set by the computerized control system in the bituminous distributor for the cutback asphalt, asphalt binder, or the asphalt emulsion. This value is typically represented by units of g/yd<sup>2</sup>.

#### 1.2.7 Emulsion Break

Emulsion break, also referred to as break or breaking, is the initiation of asphalt binder droplets coalescing and water separating within the emulsion, at which point color begins to change from brown to black.

#### 1.2.8 Emulsion Set

Emulsion set, also referred to as cure or curing, is the completion of emulsion breaking when water has evaporated, leaving behind a thin film of asphalt binder residue.

#### 1.2.9 Certificate of Analysis (COA)

The COA is the manufacturer's Certificate of Compliance (COC) including all applicable test results required by the specifications.

#### 1.2.10 Certificate of Compliance (COC)

The manufacturer's certification stating that materials or assemblies furnished fully comply with the requirements of the contract. Provide signed COC by the manufacturer's authorized representative. The COC may also be referred to as the Bill of Lading.

### 1.2.11 Screenings

Screenings are a uniformly sized, fine, sandy material with some silt particles. The term screening is used to designate the finer fraction of crushed stone that accumulates after primary and secondary crushing and separation on a No. 4 sieve. Screenings commonly range in particle size from 1/8 in down to finer than No. 200 sieve. The size distribution, particle shape, and other physical properties can be somewhat different from one quarry location to another, depending on the geological source of the rock quarried, the crushing equipment used, and the method used for coarse aggregate separation. Screenings generally contain freshly fractured faces, have a fairly uniform gradation, and do not usually contain large quantities of plastic fines.

### 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

Equipment; G

Distributor Radar or Distance Measurement Instrument (DMI)  
Calibration; G

#### SD-03 Product Data

Prime Coat Certificate Of Analysis (COA); G

Tack Coat Certificate Of Analysis (COA); G

#### SD-06 Test Reports

Sampling and Testing

Application Rate Calibration; G

Daily Application Rate Verification

#### SD-07 Certificates

Certificates Of Compliance (COC)

### 1.4 DELIVERY, STORAGE, AND HANDLING

Inspect the materials delivered to the site for contamination and damage. Unload and store the materials with minimal handling. Do not allow asphalt emulsions to freeze or boil during transport or storage. Asphalt emulsions, if allowed to freeze or boil, may cause the asphalt emulsion to break. Remove this material from site if allowed to freeze or boil.

### 1.5 ENVIRONMENTAL REQUIREMENTS

Apply bituminous coat only when the surface to receive the bituminous coat is dry. A limited amount of moisture (approximately 0.03 gallon/square yard) can be sprayed on the surface of unbound material when prime coat is

used to improve coverage and penetration of asphalt material. Apply bituminous coat only when the atmospheric temperature in the shade is 40 degrees F or above and when the temperature has not been below 35 degrees F for the 12 hours prior to application, unless otherwise directed.

## PART 2 PRODUCTS

### 2.1 EQUIPMENT

Submit equipment, tools and machines used in the work. Maintain the equipment in satisfactory working condition at all times.

#### 2.1.1 Bituminous Distributor

Provide a self propelled pressure distributor with pneumatic tires of such size and number to prevent rutting, shoving or otherwise damaging the surface being sprayed. Provide a bituminous distributor capable of circulating and agitating the bituminous material during the heating process. The distributor truck is required to have a ground speed control device (radar or contact-wheel: DMI) interconnected with the asphalt pump such that the desired application rate will be supplied at any speed. Include with the distributor equipment a tachometer, pressure gauges, volume-measuring devices, adequate heaters for heating of materials to the proper application temperature, a thermometer for reading the temperature of tank contents, and a hand hose or wand attachment suitable for applying bituminous material manually to areas inaccessible to the distributor. A uniform double or triple overlap is required to be produced by the equipped spray bar. Equip the distributor and spray bar with an instantaneous shutoff. No dripping of material from the spray bar is allowed after shutoff.

Design and equip the distributor to spray the bituminous material in a uniform coverage at the specified temperature, at readily determined and controlled total liquid rates from 0.03 to 1.0 gallon per square yard, with a pressure range of 25 to 75 psi and with an allowable variation from the specified rate of not more than plus or minus 5 percent, and at variable widths.

##### 2.1.1.1 Distributor Radar or Distance Measurement Instrument (DMI) Calibration

The radar or DMI mounted on the distributor truck, which monitors the travel speed and distance traveled, will be calibrated within 6-months of performing the. Provide certification of radar or DMI calibration with date of calibration by an officer of the company that operates the distributor truck stating the radar or DMI has been calibrated per the distributor manufacturer's instructions.

##### 2.1.1.2 Sampling Device

Equip the bituminous distributor and transport tanks with a spigot-type sampling device.

##### 2.1.1.3 Temperature Sensing Device

Equip the bituminous distributor and transport tanks with a minimum of 2-inch dial type thermometer with a temperature range of 50 degrees F to 500 degrees F, with increments having resolution of 25 degree F or finer. Locate the thermometer near the midpoint of the tank's length and within

the middle third of the tank's height, or as specified by the manufacturer. Enclose the thermometer in a well with a protective window or by other means as necessary to keep the instrument clean and in the proper working condition.

#### 2.1.2 Spray Bar Nozzles

On the spray bar, each nozzle is required to be a fan nozzle and be at the same spray angle as all other nozzles except for the outermost left and outermost right nozzle which will be a end nozzle (half-fan) such that the spray stays to the inside of the spray bar, unless otherwise approved by the Government. Orient the nozzles of the spray bar approximately 30-degrees from the axis of the spray bar, unless otherwise directed by the equipment manufacturer. Provide nozzles on the spray bar that produce the same flow rate, at the same distance above the pavement. Change the nozzles on the spray bar, as appropriate, for the material being applied and when substantial adjustments are required to the application rate.

#### 2.1.3 Heating Equipment for Storage Tanks

Use steam, electric, or hot oil heaters for heating the bituminous material. Fix an armored thermometer to the tank with a temperature range from 50 degrees F to 500 degrees F, with increments having resolution of 25 degree F or finer so that the temperature of the bituminous material may be determined at all times.

#### 2.1.4 Cleaning Equipment

Provide cleaning equipment suitable for removing and cleaning loose material from the pavement surface. If using street sweeper type equipment, equip the street sweeper with a water tank, dust control spray assembly, both a pick-up and gutter broom, and a debris hopper.

### 2.2 PRIME COAT MATERIAL

Provide the prime coat Certificate of Analysis (COA), including specific gravity, for the product specified below. COA's should be provided at preconstruction, prior to Application Rate Calibration, and any other COA's during production:

#### 2.2.1 Cutback Asphalt

Provide cutback asphalt conforming to ASTM D2027/D2027M, Grade MC-70.

### 2.3 TACK COAT MATERIAL

Provide the tack coat Certificate of Analysis (COA), including specific gravity, for the product specified below. No dilution is allowed for tack coat applications.

#### 2.3.1 Emulsified Asphalt

Provide emulsified asphalt conforming to ASTM D977, Type SS-1 or SS1h or ASTM D2397/D2397M, Type CSS-1 or CSS-1h.

### PART 3 EXECUTION

#### 3.1 PREPARATION OF ASPHALT STORAGE AND BITUMINOUS DISTRIBUTOR

Most anionic and cationic emulsions are not compatible. Thoroughly clean the asphalt emulsion storage and bituminous distributor if previous asphalt emulsion used is non-compatible with the specified emulsion. As an example, if CSS-1h (cationic) was utilized in the distributor previously, and the specified emulsion is a SS-1h (anionic), this would require the storage to be thoroughly cleaned prior to receiving the material and the bituminous distributor storage tanker to be thoroughly cleaned prior to depositing into the bituminous distributor storage tanker.

Ensure bituminous material is at the recommended application temperature and it has been thoroughly cycled through the distributor bar. Test the bituminous distributor under pressure by means of a test shot area (outside the project limits) to ensure there are no leaks or dripping for the nozzles after shut-off.

#### 3.2 PREPARATION OF SURFACE

Immediately before applying the bituminous coat, remove all loose material, dirt, clay, or other objectionable material from the surface to be treated by means of a power broom or blower supplemented with hand brooms. Apply treatment only when the surface is dry and clean.

#### 3.3 TRIAL APPLICATIONS AND CALIBRATIONS

##### 3.3.1 Trial Applications

Trial applications below are for the initial settings of the bituminous distributor computer controlled application rate settings prior to performing the APPLICATION RATE CALIBRATION.

##### 3.3.2 Prime Coat Trial Application Rate

Unless otherwise authorized, apply the trial application rate of bituminous materials in the amount of 0.15 gallon per square yard (shot rate). For emulsions, make other trial applications using various amounts of material or adjusting other setting as may be deemed necessary to meet the residual application rate and uniform coverage.

##### 3.3.3 Tack Coat Trial Application Rate

Unless otherwise authorized, apply the trial application rate of bituminous tack coat materials in the amount of 0.06 gallons per square yard. Make other trial applications using various amounts of material or adjusting other setting as may be deemed necessary to meet the residual application rate and uniform coverage.

##### 3.3.4 Application Rate Calibration

Provide all equipment, materials, and labor necessary to calibrate the application rate produced from the bituminous distributor per the following guidance. Each distributor truck proposed for use on the project will have the application rate calibrated for each material type proposed for use. Perform the application rate calibration after the distributor arrives on the project, after the test shot, and at least 24 hours prior to use for application of prime coat and tack coat. Calibrate

the application rate in accordance with ASTM D2995. If utilizing a cutback or asphalt binder, utilize ASTM D2995 Option A. If utilizing an emulsified asphalt, utilize ASTM D2995 Option B. Provide pads made from Berber carpet (or other approved durable absorbent pad) with rubber or waterproof backing measuring 12 inches by 12 inches. For transverse testing, stack pads end-to-end that spans the maximum width of the spray bar. For longitudinal testing, stack three sets of six pads end-to-end longitudinally with 100 foot separation between sets.

Measure the transverse and longitudinal application rates with all nozzles inserted in the distributor bar. Submit the results for the application rate calibration in the longitudinal direction and the transverse direction to the Government identifying, at a minimum, the following items:

- a. Project name, Contract number, testing date.
- b. Emulsified, cutback, or asphalt binder material.
- c. Distributor make, model and serial number.
- d. Distributor setup at time of calibration including target application rate (shot rate as shown on the computer control system), spray bar height, and distributor truck speed or motor RPM.
- e. Dry weight of each pad prior to application.
- f. Wet weight of each pad immediately after application.
- g. For emulsions, oven dry each pad until constant mass. Record oven dry mass of each pad in 20 minute increments. Mass at the end of a 60 minute oven dry period is considered constant mass.
- h. For emulsions, residual asphalt rate for each pad and average residual asphalt rate. For cutbacks, shot rate for each pad and average shot rate.

For the Application Rate Calibration to be acceptable, provide the average residual asphalt rate for emulsions or the average shot rate for cutbacks and asphalt binder in compliance with Table 3a or Table 3b and no individual pad rate is to vary more than 20 percent from the average. Perform the Estimating Application Rate of Bituminous Distributors in the presence of the project QC staff and the Government. Reference ATTACHMENT 1. If the application rate calibration fails to meet the requirements of this section, make adjustments to the distributor setup, shot rate or other settings as appropriate, and re-perform the application rate calibration until the results are within an acceptable range. Do not modify the distributor setup, or shot rate after application rate calibration is accepted without approval by the Government. Use ASTM D2995 to determine the estimation of application rate of bituminous distributors every 14 days of production, or as determined necessary by the Government.

### 3.3.5 Daily Application Rate Verification

Following acceptable results as outlined in paragraph APPLICATION RATE CALIBRATION, perform daily application rate verification each day when the distributor is in use and provide results daily during execution. The production application rates will utilize the volume method of determination as follows:

- a. Determine the total distance to be sprayed.
- b. Calculate the area sprayed.
- c. Calculate the gallons of material applied by subtracting the beginning volume by the ending volume. Utilizing the dipstick which has been provided with the distributor truck or the onboard meter.
- d. Correct for temperature back to 60 degrees F by applying correction factor as provided in ASTM D1250.
- e. Calculate and report the temperature corrected shot rate by dividing the corrected gallons per item d. by the total area sprayed.

3.4 APPLICATION RATE CORRECTION

If the daily application rate verification varies by more than 0.015 gallon per square yard from the shot rate established during application rate calibration that met the rates in Table 3a or Table 3b, immediately re-perform the application rate calibration in accordance with paragraph APPLICATION RATE CALIBRATION and ensure results are in compliance with the rates specified in Table 3a or Table 3b prior to applying additional prime coat or tack coat.

3.5 APPLICATION TEMPERATURE

3.5.1 Viscosity Relationship

Apply bituminous material at a temperature that will provide a viscosity between 10.0 and 60.0 seconds, Saybolt Furol in accordance with ASTM D88/D88M or between 20 and 120 centistokes in accordance with ASTM D2170/D2170M. Furnish the temperature viscosity relation to the Contracting Officer.

3.5.2 Temperature Ranges

The viscosity requirements determine the application temperature to be used. Table 2 presents a normal range of application temperatures. If Table 2 is different than the manufacturer's recommendation, use the manufacturer's recommendation.

Table 2	
Tack Coat or Prime Coat Application Temperatures	
Cutback Asphalt	
MC-70, RC-70 <sup>(1)</sup>	120-225 degrees F
Asphalt Emulsion	
Cationic Emulsified Asphalt	130-170 degrees F
Anionic Emulsified Asphalt	150-180 degrees F

Table 2
Tack Coat or Prime Coat Application Temperatures
(1) Some temperatures within these ranges provided may exceed the flash point for certain rapid cure cutbacks. Care should be taken in their heating.

3.6 APPLICATION

3.6.1 General

Following preparation and subsequent inspection of the surface, apply the prime coat or tack coat with the distributor at the specified rate with uniform distribution over the surface to be treated. Properly treat all areas and spots, not capable of being sprayed with the distributor, with the hand spray. Until the succeeding layer of pavement is placed, maintain the surface by protecting the surface against damage and by repairing deficient areas at no additional cost to the Government. If required, spread clean dry sand to effectively blot up any excess bituminous material. No smoking, fires, or flames other than those from the heaters that are a part of the equipment are permitted within 25 feet of heating, distributing, and transferring operations of cutback materials. Prevent all traffic, except for paving equipment used in constructing the surfacing, from using the underlying material, whether primed or not, until the surfacing is completed.

3.6.2 Prime Coat

Apply the prime coat at locations shown on the Drawings only when the underlying material meets the specified material density requirements, and the moisture content is within 2 percent of optimum moisture. Application should be achieved within the limits of the temperature described in paragraph ENVIRONMENTAL REQUIREMENTS and quantities to achieve the rate of residual asphalt shown in Table 3a. At the time of priming, ensure that the base is firm, unyielding and in such condition that no undue distortion will occur. Ensure the prime coat adheres to the underlying material. Apply the prime coat material using a bituminous distributor. To obtain uniform application of the prime coat on the surface treated at the junction of previous and subsequent applications, spread building paper on the surface for a sufficient distance back from the ends of each application to start and stop the prime coat on the paper and to ensure that all sprayers will operate at full force on the surface to be treated. Immediately after application, remove and discard the building paper.

Table 3a		
Prime Coat Application Rates		
Surface Type	Product Type	Rate (gal/yd <sup>2</sup> )
Unbound Layers	Cutback Asphalt	0.08 - 0.18 (shot rate)



Table 3a		
Prime Coat Application Rates		
Surface Type	Product Type	Rate (gal/yd <sup>2</sup> )
(1) Emulsion prime coats may be diluted up-to a 1 to 1 dilution rate.		

3.6.3 Tack Coat

Immediately following the preparation of the surface for treatment, apply the tack coat by means of the distributor, within the limits of the temperature described in paragraph ENVIRONMENTAL REQUIREMENTS and in quantities to achieve the rate of residual application rates shown in Table 3b. Ensure the surface is clean and dry. Apply tack coat at the locations shown on the Drawings sufficiently in advance of placing the asphalt mixture to permit breaking and initial stages of curing. Do not apply tack coat so far in advance that it might lose its adhesiveness as a result of being covered with dust or other foreign material. When using a spray paver with appropriate tack coat products, tack coat breaking requirements do not apply. Dilution of tack coat is prohibited. A tack coat should be applied to every bound surface (asphalt or concrete pavement) that is being overlaid with asphalt mixture and at transverse and longitudinal joints. Apply the bituminous material so that uniform distribution is obtained over the entire surface to be treated. Treat lightly coated areas and spots missed by the distributor by spraying with a hand wand or using other approved method. To obtain uniform application of the tack coat, at the junction of previous and subsequent applications, spread building paper on the surface for a sufficient distance back from the ends of each application to start and stop the tack coat on the paper and to ensure that all sprayers will operate at full force on the surface to be treated. Immediately after application, remove and discard the building paper. If blotter aggregate is used, lightly sweep with a power broom, or other approved means, to remove any excess blotter aggregate. Maintain and protect the treated surface from damage until the succeeding course of pavement is placed.

Table 3b		
Tack Coat Application Rates <sup>(1,3,4)</sup>		
Surface Type	Residual Rate (gal/yd <sup>2</sup> )	Approximate Bar Rate Undiluted <sup>(2)</sup> (gal/yd <sup>2</sup> )
New Asphalt (between layers)	0.02 - 0.05	0.03 - 0.07
Existing Asphalt	0.04 - 0.07	0.06 - 0.11
Milled Surface	0.04 - 0.08	0.06 - 0.12

Table 3b		
Tack Coat Application Rates <sup>(1,3,4)</sup>		
Surface Type	Residual Rate (gal/yd <sup>2</sup> )	Approximate Bar Rate Undiluted <sup>(2)</sup> (gal/yd <sup>2</sup> )
Portland Cement Concrete	0.03 - 0.05	0.05 - 0.08
(1) Dilution of tack coat is not allowed		
(2) Assumes emulsion is 33 percent water and 67 percent asphalt		
(3) Emulsified asphalt is prohibited to be applied at application rates over 0.12 gal/yd <sup>2</sup>		
(4) Residual rate is the same as bar rate when using hot-applied asphalt binders. Use residual rate tolerances as shown above for target when using hot-applied asphalt binders.		

### 3.7 FIELD QUALITY CONTROL

Certificates of compliance (COC) for asphalt materials delivered will be obtained and checked to ensure that specification requirements are met. Quantities of applied material will be determined. Prime coat materials when emulsions are used can be diluted on site with potable water up to 1 part water to 1 part emulsion, as long as the residual rate is still being met. Do not dilute tack coat materials. If requested by the Government, obtain samples of the bituminous material under the supervision of the Government per paragraph SAMPLING and send for analysis.

#### 3.7.1 Sampling and Testing

Furnish certified copies of the manufacturer's test reports indicating temperature-viscosity relationship for asphalt materials and compliance with applicable specified requirements, not less than 5 days before the material is required in the work.

#### 3.7.2 Sampling

Unless otherwise specified, sample bituminous material in accordance with ASTM D140/D140M.

### 3.8 PRIME COAT SET PERIOD

Allow the prime coat to set without being disturbed for a period of at least 48 hours or longer, as may be necessary to attain penetration into the treated course. Furnish and spread enough blotter aggregate to effectively blot up excess bituminous material.

### 3.9 TACK COAT BREAKING PERIOD

Following application of an emulsified asphalt tack coat and prior to application of the succeeding layer of asphalt mixture, allow emulsified asphalt tack coats to break. No break period is required for cutback or

hot-applied asphalt binder tack coat products.

### 3.10 TRAFFIC CONTROLS

Maintain the primed surface and tacked surface in good condition until the succeeding layer of pavement is placed, by protecting the surface against damage and by repairing and recoating deficient areas. Keep traffic off surfaces freshly treated with bituminous material. Provide sufficient warning signs and barricades so that traffic will not travel over freshly treated surfaces.

### 3.11 ATTACHMENT

#### **ATTACHMENT 1: Estimating Application Rate of Bituminous Distributors**

-- End of Section --

SECTION 32 12 16.16  
ROAD-MIX ASPHALT PAVING  
11/20

PART 1 GENERAL

1.1 PERCENT PAYMENT

1.1.1 Method of Measurement

Measurement of the quantity of hot-mix warm-mix asphalt pavement, per ton placed and accepted, will be made for the purposes of assessing the pay factors stipulated below.

1.1.2 Basis of Payment

The measured quantity of hot-mixed warm-mixed asphalt pavement 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 in paragraph PERCENT PAYMENT, a unit price of per ton will be used for purposes of calculating the payment reduction.

1.1.3 Lot Pay Factor

The lot pay factor is determined by taking the lowest computed pay factor based on either laboratory air voids, in-place density, smoothness, or grade (each discussed below). Remove and replace lots when the lowest computed pay factor requires rejection. At the end of the project calculate the average pay factor for all lots. If this average lot pay factor exceeds 95.0 percent and no individual lot has a pay factor less than 75.0 percent, then the percent payment for the entire project will be 100 percent of the unit bid price. If the average lot pay factor is less than 95.0 percent, then each lot will be paid for at the unit price multiplied by the lot's pay factor. For any lots which are less than 2,000 tons, a weighted lot pay factor will be used to calculate the average lot pay factor. When work on a lot is required to be terminated before all four sublots are completed, the results from the completed sublots will be analyzed to determine the percent payment for the lot following the same procedures and requirements for full lots but with fewer or more test results as determined in paragraph PAVEMENT LOTS.

1.1.4 Payment Adjustment for Laboratory Air Voids

Laboratory air void calculations for each lot will use the average theoretical maximum density values obtained for the lot. Determine the average TMD in accordance with paragraph THEORETICAL MAXIMUM DENSITY (TMD). The mean absolute deviation of the laboratory air void contents (one from each subplot) from the JMF air void content will be evaluated as shown in the example below and a pay factor will be determined from Table 1. When 0 percent payment is determined, remove and replace the rejected lot at least 4 inches into the cold (existing) lane adjacent to the longitudinal joint.

Table 1. Pay Factor Based on Laboratory Air Voids	
Mean Absolute Deviation of Lab Air Voids from JMF	Pay Factor, percent
0.60 or less	100
0.61 - 0.80	98
0.81 - 1.00	95
1.01 - 1.20	90
Above 1.20	Reject (0)

1.1.4.1 Pay Factor Example for Laboratory Air Voids

An example of the computation of mean absolute deviation for laboratory air voids is as follows: Assume that the laboratory air voids are determined from 4 sublots where one set of laboratory compacted specimens is from a single subplot. The laboratory air voids for the 4 sublots are determined to be 3.5, 3.0, 4.0, and 3.7. Assume that the target air voids from the JMF is 4.0. The mean absolute deviation is then:

$$\text{Mean Absolute Deviation} = (|3.5 - 4.0| + |3.0 - 4.0| + |4.0 - 4.0| + |3.7 - 4.0|) / 4$$

$$\text{Mean Absolute Deviation} = (0.5 + 1.0 + 0.0 + 0.3) / 4 = (1.8) / 4 = 0.45$$

The mean absolute deviation for laboratory air voids is determined to be 0.45. It can be seen from Table 1 that the lot's pay factor based on laboratory air voids is 100 percent.

1.1.5 Payment Adjustment for In-place Densities

The average in-place mat and joint densities are expressed as a percentage of the average theoretical maximum density (TMD) for the lot. Determine the average TMD in accordance with paragraph THEORETICAL MAXIMUM DENSITY (TMD). The average in-place mat density and joint density for a lot are determined and compared with Table 2 to calculate a single pay factor per lot. Use the following process to determine the single pay factor for in-place density:

- a. Step 1: Determine the pay factors for mat density and joint density using Table 2.
- b. Step 2: Determine ratio of joint area to mat area. The area associated with the joint is considered to be 10 feet wide times the length of completed longitudinal construction joint in the lot. This joint area will not exceed the total lot size. The length of joint to be considered will be that length where a new lane has been placed against an adjacent lane of asphalt pavement, either an adjacent freshly paved lane or one paved at any time previously.
- c. Step 3: Compute the weighted pay factor for the joint using the formula in the example below.
- d. Step 4: Compare weighted pay factor for joint density to pay factor

for mat density and select the smaller. This selected pay factor is the pay factor based on density for the lot.

When 0 percent payment is determined for mat density, remove and replace the rejected lot at least 4 inches into the cold (existing) lane adjacent to the longitudinal joint. When 0 percent payment is determined for joint density, remove and replace the rejected longitudinal joint with a 10 feet wide paving lane that is centered over the joint.

Average Mat Density (4 Cores) (Percent of TMD)	Pay Factor, Percent	Average Joint Density (4 Cores) (Percent of TMD)
93.0 - 96.0	100.0	91.5 or above
92.9	100.0	91.4
92.8 or 96.1	99.9	91.3
92.7	99.8	91.2
92.6 or 96.2	99.6	91.1
92.5	99.4	91.0
92.4 or 96.3	99.1	90.9
92.3	98.7	90.8
92.2 or 96.4	98.3	90.7
92.1	97.8	90.6
92.0 or 96.5	97.3	90.5
91.9	96.3	90.4
91.8 or 96.6	94.1	90.3
91.7	92.2	90.2
91.6 or 96.7	90.3	90.1
91.5	87.9	90.0
91.4 or 96.8	85.7	89.9
91.3	83.3	89.8
91.2 or 96.9	80.6	89.7
91.1	78.0	89.6
91.0 or 97.0	75.0	89.5
below 91.0, above 97.0	0.0 (reject)	below 89.5

1.1.5.1 Pay Factor Example for In-place Density

An example of the computation of a pay factor (in I-P units only) based on in-place density, is as follows: Assume the following test results for field density made on the lot: (1) Average mat density = 92.2 percent (of lab TMD). (2) Average joint density = 90.5 percent (of lab TMD). (3) Total area of lot = 30,000 square feet. (4) Length of completed longitudinal construction joint = 2,000 feet.

- a. Step 1: Determine pay factor based on mat density and on joint density, using Table 2:

Mat density of 92.2 percent = 98.3 pay factor.

Joint density of 90.5 percent = 97.3 pay factor.

- b. Step 2: Determine ratio of joint area to mat area. Multiply the length of completed longitudinal construction joint by the specified 10 foot width and divide by the mat area (total paved area in the lot).

Ratio = Ratio of joint area to mat area

Ratio = (2,000 feet x 10 feet)/30,000 square feet

Ratio = 0.6667

- c. Step 3: Weighted pay factor (wpf) for joint is determined as indicated below:

$wpf = \text{joint pay factor} + (100 - \text{joint pay factor}) \times (1 - \text{ratio})$

$wpf = 97.3 + (100 - 97.3) \times (1 - 0.6667) = 98.2 \text{ percent}$

- d. Step 4: Compare weighted pay factor for joint density to pay factor for mat density and select the smaller:

Pay factor for mat density: 98.3 percent.

Weighted pay factor for joint density: 98.2 percent

Selected pay factor: 98.2 percent

#### 1.1.6 Payment Adjustment for Plan Grade

When more than 5 percent of all measurements made within a lot are outside the 0.05 foot tolerance, the pay factor based on grade for that lot will be 95 percent. For individual locations where the grade exceeds 0.075 foot tolerance, remove the surface lift full depth and replace the lift with asphalt pavement to meet specification requirements at no additional cost to the Government. High spots can be diamond ground as an alternative to remove and replace in order to meet grade requirements for the lot and at individual locations.

### 1.2 PAYMENT

#### 1.2.1 Method of Measurement

The amount paid for will be the number of tons of hot-mix asphalt pavement mixture used in the accepted work. Weigh the hot-mix asphalt pavement mixture after mixing. No separate payment will be made for weight of asphalt cement material incorporated herein.

#### 1.2.2 Basis of Payment

Quantities of hot-mix asphalt pavement, determined as specified above, will be paid for at respective contract unit prices. Payment will constitute full compensation for furnishing all materials, equipment, plant, and tools; and for all labor and other incidentals necessary to complete work required by this section of the specification.

### 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 ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

- |              |   |
|--------------|---|
| AASHTO M 156 | (2013; R 2017) Standard Specification for Requirements for Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures |
| AASHTO T 304 | (2011; R 2015) Standard Method of Test for Uncompacted Void Content of Fine Aggregate                                       |
| AASHTO T 329 | (2015) Standard Test Method for Moisture Content of Hot Mix Asphalt (HMA) by Oven Method                                    |

#### ASPHALT INSTITUTE (AI)

- |         |                                   |
|---------|-----------------------------------|
| AI MS-2 | (2015) Asphalt Mix Design Methods |
|---------|-----------------------------------|

#### ASTM INTERNATIONAL (ASTM)

- |                 |  |
|-----------------|--|
| ASTM C29/C29M   | (2017a) Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate   |
| ASTM C88        | (2018) Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate                                      |
| ASTM C117       | (2023) Standard Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing                                |
| ASTM C127       | (2015) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate                           |
| ASTM C128       | (2015) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate                             |
| 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 C142/C142M | (2017) Standard Test Method for Clay Lumps and Friable Particles in Aggregates   |
| ASTM C566       | (2013) Standard Test Method for Total  |



	Evaporable Moisture Content of Aggregate by Drying
ASTM D75/D75M	(2019) Standard Practice for Sampling Aggregates
ASTM D242/D242M	(2009; R 2014) Mineral Filler for Bituminous Paving Mixtures
ASTM D979/D979M	(2015) Sampling Bituminous Paving Mixtures
ASTM D2041/D2041M	(2011) Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
ASTM D2172/D2172M	(2017; E 2018) Standard Test Methods for Quantitative Extraction of Asphalt Binder from Asphalt Mixtures
ASTM D2419	(2014) Sand Equivalent Value of Soils and Fine Aggregate
ASTM D2726/D2726M	(2019) Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures
ASTM D3203/D3203M	(2017) Standard Test Method for Percent Air Voids in Compacted Asphalt Mixtures
ASTM D3665	(2012; R 2017) Standard Practice for Random Sampling of Construction Materials
ASTM D3666	(2016) Standard Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials
ASTM D4791	(2019) Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
ASTM D4867/D4867M	(2009; R 2014) Effect of Moisture on Asphalt Concrete Paving Mixtures
ASTM D5361/D5361M	(2016) Standard Practice for Sampling Compacted Asphalt Mixtures for Laboratory Testing
ASTM D5444	(2015) Mechanical Size Analysis of Extracted Aggregate
ASTM D5821	(2013; R 2017) Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
ASTM D6307	(2019) Standard Test Method for Asphalt Content of Asphalt Mixture by Ignition Method

ASTM D6373	(2016) Standard Specification for Performance Graded Asphalt Binder
ASTM D6926	(2020) Standard Practice for Preparation of Asphalt Mixture Specimens Using Marshall Apparatus
ASTM D6927	(2015) Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures

#### 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 to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

##### SD-02 Shop Drawings

Placement Plan; G

##### SD-03 Product Data

Diamond Grinding Plan; G

Mix Design; G

Contractor Quality Control; G

##### SD-04 Samples

Aggregates

Asphalt Cement Binder

##### SD-06 Test Reports

Aggregates; G

QC Monitoring

##### SD-07 Certificates

Asphalt Cement Binder; G

Laboratory Accreditation and Validation

#### 1.5 ACCEPTANCE

##### 1.5.1 Acceptability of Work

Acquire the services of an independent commercial laboratory to perform acceptance testing. Acceptance of the plant produced mix and in-place requirements will be on a lot to lot basis. The materials and the pavement itself will be accepted on the basis of production testing. The Government may make check tests from split samples to validate the results of the production testing. Testing performed by the Government does not

reduce the required testing of the independent commercial laboratory. Split samples will be taken for Government testing to reduce the variability between the independent commercial laboratory and the Government's test results. When the difference between the independent commercial laboratory and the Government's test results for split samples exceed the acceptable range of two results for multilaboratory precision for the appropriate test method (i.e. ASTM) then at least one of the laboratories is determined to be in error. An evaluation of procedures and equipment in both laboratories will be made to determine the cause(s) for the differences. Develop steps to correct procedures and equipment to bring multilaboratory precision to within acceptable limits.

#### 1.5.2 Acceptance Requirements

Provide all sampling and testing required for acceptance and payment adjustment. Where appropriate, adjustments in percent payment acceptance for individual lots of asphalt pavement will be made based on laboratory air voids, in-place density, smoothness, and grade in accordance with the following paragraphs. Surface smoothness and grade determinations will be made on the lot as a whole. Exceptions or adjustments to this will be made in situations where the mix within one lot is placed as part of both the intermediate and surface courses, thus smoothness and grade measurements for the entire lot cannot be made.

#### 1.5.3 Pavement Lots

A standard lot for all requirements is equal to one day's production or 2,000 tons, whichever is smaller. Divide each lot into four equal sublots in order to evaluate laboratory air voids and in-place density. 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 and the total number of sublots (i.e. 5 or 6 sublots) is used for acceptance criteria. Include partial lots at the end of asphalt production into the previous lot. Complete and report all theoretical maximum density, laboratory air voids, and in-place density testing within 24 hours after construction of each lot.

#### 1.5.4 Sublot Sampling

Take one mixture sample for each sublot in accordance with ASTM D979/D979M from a random truck or another location for determining theoretical maximum density, laboratory air voids, any additional testing the Government desires, and Contractor Quality Control. All samples will be selected randomly, using commonly recognized methods of assuring randomness conforming to ASTM D3665 and employing tables of random numbers or computer programs.

#### 1.5.5 Additional Sampling and Testing

The Government reserves the right to direct additional samples and tests for any area which appears to deviate from the specification requirements. The cost of any additional testing will be paid for by the Government. Testing in these areas will be treated as a separate lot. Payment Acceptance will be made for the quantity of asphalt pavement represented by these tests in accordance with the provisions of this section.

#### 1.5.6 Theoretical Maximum Density (TMD)

Measure theoretical maximum density one time for each subplot in accordance with ASTM D2041/D2041M for purposes of calculating laboratory air voids and determining in-place density. The average TMD for each lot will be determined as the average TMD of the random subplot samples. When the TMD on both sides of a longitudinal joint is different, the average of these two TMD values will be used as the TMD needed to calculate the percent joint density.

#### 1.5.7 Laboratory Air Voids

Prepare one set of laboratory compacted specimens for each subplot in accordance with ASTM D6926 using the hand-held hammer for the Marshall Method. Provide three test specimens prepared from the same sample for each set of laboratory compacted specimens. Compact the specimens within 2 hours of the time the mixture was loaded into trucks at the asphalt plant. Do not reheat samples prior to compaction. Provide insulated containers as necessary to maintain the sample temperature. Measure the bulk density of laboratory compacted specimens in accordance with ASTM D2726/D2726M. Determine laboratory air voids from one set (three laboratory compacted specimens) for each subplot sample in accordance with ASTM D3203/D3203M.

##### 1.5.7.1 Tolerance

Provide laboratory air voids with a mean absolute deviation of 1.00 percent or less from the JMF for each lot. Remove and replace lots that do not meet the laboratory air voids requirement at least 4 inches into the cold (existing) lane adjacent to the longitudinal joint, at no additional cost to the Government. The mean absolute deviation of the laboratory air void contents from the JMF air void content will be evaluated as shown in the example below.

##### 1.5.7.2 Calculating Laboratory Air Voids

Laboratory air void calculations for each lot will use the average theoretical maximum density values obtained for the lot. Determine the average TMD in accordance with paragraph THEORETICAL MAXIMUM DENSITY (TMD). The mean absolute deviation of the laboratory air void contents (one from each subplot) from the JMF air void content will be evaluated as in the following example:

Assume that the laboratory air voids are determined from 4 sublots where one set of laboratory compacted specimens is from a single subplot. The laboratory air voids for the 4 sublots are determined to be 3.5, 3.0, 4.0, and 3.7. Assume that the target air voids from the JMF is 4.0. The mean absolute deviation is then:

$$\text{Mean Absolute Deviation} = (|3.5 - 4.0| + |3.0 - 4.0| + |4.0 - 4.0| + |3.7 - 4.0|)/4$$

$$\text{Mean Absolute Deviation} = (0.5 + 1.0 + 0.0 + 0.3)/4 = (1.8)/4 = 0.45$$

The mean absolute deviation for laboratory air voids is determined to be 0.45. It can be seen that 0.45 is less than 1.00 percent. The lot is acceptable for laboratory air voids.

#### 1.5.8 In-place Density

Obtain one random 4 inch or 6 inch diameter core from the mat and joint of each subplot in accordance with ASTM D5361/D5361M for determining in-place density. Cut samples neatly with a diamond core drill bit. Obtain random cores that are the full thickness of the layer being placed. Select core locations randomly using the procedures contained in ASTM D3665. Locate cores for mat density no closer than 12 inches from a transverse or longitudinal joint including the pavement edge. Center all cores for joint density on the joint. Discard samples that are clearly defective as a result of sampling and take an additional random core. When the random core is less than 1 inch thick, it will not be included in the analysis. In this case, obtain another random core sample. Clean and tack coat dry core holes before filling with asphalt mixture. Fill all core holes with asphalt mixture and compact using a standard Marshall hammer to the density specified. Provide all tools, labor, and materials for cutting samples, cleaning, and filling the cored pavement. Measure in-place density in accordance with ASTM D2726/D2726M using each core obtained from the mat and joint.

##### 1.5.8.1 Tolerance

Provide a minimum in-place mat density of 93.0 percent and a minimum in-place joint density of 90.0 percent for each lot. The average in-place mat and joint densities are expressed as a percentage of the average theoretical maximum density (TMD) for the lot. Determine the average TMD in accordance with paragraph THEORETICAL MAXIMUM DENSITY (TMD). Remove and replace lots that do not meet the in-place mat density requirement at least 4 inches into the cold (existing) lane adjacent to the longitudinal joint, at no additional cost to the Government. Remove and replace the longitudinal joint when the lot does not meet the in-place joint density, at no additional cost to the Government. Use a 10 feet wide paving lane that is centered over the joint.

#### 1.5.9 Surface Smoothness

Use a straightedge for measuring surface smoothness. Smoothness requirements do not apply over crowns or grade breaks. Maintain detailed notes of the testing results and provide a copy to the Government immediately after each day's testing.

##### 1.5.9.1 Smoothness Requirements

###### 1.5.9.1.1 Straightedge Testing

Provide finished surfaces of the pavements with no abrupt change of 1/4 inch or more when checked with an approved 12 foot straightedge. Remove and replace surface lift lots when the surface smoothness exceeds 3/8 inch, at no additional cost to the Government. High spots can be diamond ground as an alternative to remove and replace in order to meet surface smoothness requirements at individual locations.

##### 1.5.9.2 Testing Method

After the final rolling, but not later than 24 hours after placement, test the surface of the pavement in each entire lot in a manner to reveal surface irregularities exceeding the tolerances specified above. If any pavement areas are diamond ground, retest these areas immediately after diamond grinding. The maximum area allowed to be corrected by diamond

grinding is 10 percent of the total area of the lot. Check a number of random locations along with any observed suspicious locations primarily at transverse and longitudinal joints with the straightedge.

#### 1.5.9.2.1 Straightedge Testing

Use the straightedge to measure abrupt changes in surface smoothness. Hold the straightedge in contact with the pavement surface and measure the maximum distance between the straightedge and the pavement surface. Determine the amount of surface irregularity by placing the freestanding (unleveled) straightedge on the pavement surface and allowing it to rest upon the two highest spots covered by its length, and measuring the maximum gap between the straightedge and the pavement surface in the area between these two high points.

#### 1.5.9.2.2 Bumps ("Must Grind" Areas)

Reduce any bumps ("must grind" areas) which exceed 0.4 inch in height by diamond grinding until they do not exceed 0.3 inch when retested. Taper diamond grinding in all directions to provide smooth transitions to areas not requiring diamond grinding. The following will not be permitted: (1) skin patching for correcting low areas, (2) planing or milling for correcting high areas.

#### 1.5.10 Plan Grade

Provide a final wearing surface of pavement conforming to the elevations and cross sections shown and not vary more than 0.05 foot from the plan grade established and approved at site of work. Within 5 working days after completion of a particular lot incorporating the final wearing course, test the final wearing surface of the pavement for conformance with specified plan grade requirements. Match finished surfaces at juncture with other pavements with finished surfaces of abutting pavements. Deviation from the plan elevation will not be permitted in areas of pavements where closer conformance with planned elevation is required for the proper functioning of drainage and other appurtenant structures involved. For parking lots, the grade will be determined by running lines of levels at intervals of 25 feet or less longitudinally and transversely to determine the elevation of the completed pavement surface.

Diamond grinding can be used to remove high spots to meet grade requirements. Skin patching for correcting low areas or planing or milling for correcting high areas will not be permitted. Maintain detailed notes of the results of the testing and provide a copy to the Government immediately after each day's testing. Remove and replace surface lift lots when individual locations exceed 0.05 foot tolerance, at no additional cost to the Government. High spots can be diamond ground as an alternative to remove and replace in order to meet plan grade requirements at individual locations.

#### 1.5.11 Laboratory Accreditation and Validation

Provide laboratories used to develop the Job Mix Formula (JMF), perform acceptance testing, and Contractor Quality Control testing that meet the requirements of ASTM D3666. Provide laboratories with a masonry saw having a diamond blade for trimming pavement cores and samples. Perform all required test methods by an accredited laboratory. Schedule and provide payment for laboratory inspections. Additional payment or a time extension due to failure to acquire the required laboratory accreditation is not allowed. Submit a certificate of compliance signed by the manager

of the laboratory stating that it meets these requirements to the Government prior to the start of construction. At a minimum, include the following certifications:

- a. Qualifications of personnel; laboratory manager, supervising technician, and testing technicians.
- b. A listing of equipment to be used in developing the job mix.
- c. A copy of the laboratory's quality control system.

#### 1.6 ENVIRONMENTAL REQUIREMENTS

Do not place the asphalt mixture upon a wet surface or when the surface temperature of the underlying course is less than specified in Table 3 Table 1. The temperature requirements may be waived by the Government, if requested; however, meet all other requirements including compaction.

Table 3. Table 1. Surface Temperature Limitations of Underlying Course	
Mat Thickness, inches	Degrees F
3 or greater	40
Less than 3	45

### PART 2 PRODUCTS

#### 2.1 SYSTEM DESCRIPTION

Perform the work consisting of pavement courses composed of mineral aggregate and asphalt material heated and mixed in a central mixing plant and placed on a prepared course. Provide asphalt pavement designed and constructed in accordance with this section conforming to the lines, grades, thicknesses, and typical cross sections shown on the drawings. Construct each course to the depth, section, or elevation required by the drawings and rolled, finished, and approved before the placement of the next course. Submit proposed Placement Plan indicating lane widths and longitudinal joints for each course or lift.

##### 2.1.1 Asphalt Mixing Plant

Provide plants used for the preparation of asphalt mixture conforming to the requirements of AASHTO M 156 with the following changes:

###### 2.1.1.1 Truck Scales

Weigh the asphalt mixture on approved scales, or on certified public scales at no additional expense to the Government. Inspect and seal scales at least annually by an approved calibration laboratory.

###### 2.1.1.2 Inspection of Plant

Provide access to the Government at all times, to all areas of the plant for checking adequacy of equipment; inspecting operation of the plant; verifying weights, proportions, and material properties; checking the temperatures maintained in the preparation of the mixtures and for taking samples. Provide assistance as requested, for the Government to procure

any desired samples.

#### 2.1.1.3 Storage bins

The asphalt mixture can be stored in non-insulated storage bins for a period of time not exceeding 3 hours. The asphalt mixture can be stored in insulated storage bins for a period of time not exceeding 8 hours. Provide the mix drawn from bins that meets the same requirements as mix loaded directly into trucks.

#### 2.1.2 Hauling Equipment

Provide trucks used for hauling asphalt mixture that have tight, clean, and smooth metal beds. To prevent the mixture from adhering to them, lightly coat the truck beds with a minimum amount of paraffin oil, lime solution, or other approved material. Do not use petroleum based products as a release agent. Provide each truck with a suitable cover to protect the mixture from adverse weather, contamination, and loss of material during hauling. When necessary due to long haul distance and cold weather, provide insulated truck beds with covers (tarps) that are securely fastened.

#### 2.1.3 Asphalt Pavers

Provide mechanical spreading and finishing equipment consisting of a self-powered paver, capable of spreading and finishing the mixture to the specified line, grade, and cross section. Provide paver screed capable of laying a uniform mixture to meet the specified thickness, smoothness, and grade without physical or temperature segregation, the full width of the material being placed. Provide a paver with a vibrating screed to be used during all placement.

##### 2.1.3.1 Receiving Hopper

Provide paver with a receiving hopper of sufficient capacity to permit a uniform spreading operation and a distribution system to place the mixture uniformly in front of the screed without segregation. Provide a screed that effectively produces a finished surface of the required evenness and texture without tearing, shoving, or gouging the mixture.

##### 2.1.3.2 Automatic Grade Controls

Provide a paver equipped with a control system capable of maintaining the specified screed elevation. One of three methods can be used to control grade: stringline, laser, or computerized elevations along with GPS. For multiple layers it is acceptable to control the grade in the underlying layer and control the grade of the surface layer by applying a constant thickness over the underlying layer which has been placed to the desired grade. Slope control can also be used to control the grade of the surface for roads, but is not acceptable for wide pavements such as parking lots. Provide transverse slope controller capable of maintaining the screed at the desired slope within plus or minus 0.1 percent. A ski-type device of not less than 30 ft can be used to provide improved smoothness. Use a shoe on one side of the paver to match an existing paved surface to provide a smooth joint.

#### 2.1.4 Rollers

Provide rollers in good condition and operate at slow speeds to avoid



displacement of the asphalt mixture. Provide sufficient number, type, and weight of rollers to compact the mixture to the required density while it is still in a workable condition. Do not use equipment which causes excessive crushing of the aggregate.

#### 2.1.5 Diamond Grinding

Those performing diamond grinding are required to have a minimum of three years' experience in diamond grinding. 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 is limited below. Reduce high areas by diamond grinding the asphalt pavement with approved equipment. Perform diamond grinding by sawing with saw blades impregnated with an industrial diamond abrasive. 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 asphalt pavement or joint faces. Provide diamond grinding equipment with saw blades that are 1/8-inch wide, a minimum of 60 blades per 12 inches of cutting head width, and capable of cutting a path a minimum of 3 feet wide. Diamond grinding equipment that causes raveling, fracturing of aggregate, or disturbance to the underlying material will not be allowed. The maximum area corrected by diamond grinding the surface of the asphalt pavement is 10 percent of the total area of any lot. The maximum depth of diamond grinding is 1/2 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.

Prior to production diamond grinding operations, perform a test section at the approved location, consisting of a minimum of two adjacent passes with a minimum length of 40 feet to allow evaluation of the finish and transition between adjacent passes. Production diamond grinding operations cannot be performed prior to approval.

### 2.2 AGGREGATES

Notify the Government at least 7 days before sampling aggregates. Obtain samples in accordance with ASTM D75/D75M that are representative of the materials to be used for the project. Provide aggregates consisting of crushed stone, crushed gravel, crushed slag, screenings, natural sand, and mineral filler as required. The portion of material retained on the No. 4 sieve is coarse aggregate. The portion of material passing the No. 4 sieve and retained on the No. 200 sieve is fine aggregate. The portion passing the No. 200 sieve is defined as mineral filler. Submit sufficient materials to produce 200 pounds of blended mixture for mix design verification. Submit all aggregate test results and samples to the Government at least 14 days prior to start of construction. Perform job aggregate testing no earlier than 6 months before contract award.

#### 2.2.1 Coarse Aggregate

Provide coarse aggregate consisting of sound, tough, durable particles, free from films of material that would prevent thorough coating and bonding with the asphalt material and free from organic matter and other deleterious substances. Provide coarse aggregate particles meeting the

following requirements:

- a. The percentage of loss not greater than 40 percent after 500 revolutions when tested in accordance with ASTM C131/C131M.
- b. The sodium sulfate soundness loss not exceeding 12 percent, or the magnesium sulfate soundness loss not exceeding 18 percent after five cycles when tested in accordance with ASTM C88.
- c. At least 75 percent by weight of coarse aggregate containing two or more fractured faces when tested in accordance with ASTM D5821 with fractured faces produced by crushing.
- d. The particle shape essentially cubical and the aggregate containing not more than 10 percent, by weight, of flat and elongated particles (5:1 ratio of length to thickness) when tested in accordance with ASTM D4791, Method B.
- e. Slag consisting of air-cooled, blast furnace slag with a compacted weight of not less than 75 lb/cu ft when tested in accordance with ASTM C29/C29M.
- f. Clay lumps and friable particles not exceeding 0.3 percent, by weight, when tested in accordance with ASTM C142/C142M.

#### 2.2.2 Fine Aggregate

Provide fine aggregate consisting of clean, sound, tough, durable particles. Provide aggregate particles that are free from coatings of clay, silt, or any objectionable material, contain no clay balls, and meet the following requirements:

- a. Quantity of natural sand (noncrushed material) added to the aggregate blend not exceeding 15 percent by weight of total aggregate.
- b. Individual fine aggregate sources with a sand equivalent value greater than 45 when tested in accordance with ASTM D2419.
- c. Fine aggregate portion of the blended aggregate with an uncompacted void content greater than 45.0 percent when tested in accordance with AASHTO T 304 Method A.
- d. Clay lumps and friable particles not exceeding 0.3 percent, by weight, when tested in accordance with ASTM C142/C142M.

#### 2.2.3 Mineral Filler

Provide mineral filler consisting of a nonplastic material meeting the requirements of ASTM D242/D242M.

#### 2.2.4 Aggregate Gradation

Provide a combined aggregate gradation that conforms to gradations specified in Table 4 Table 2, when tested in accordance with ASTM C136/C136M and ASTM C117, and does not vary from the low limit on one sieve to the high limit on the adjacent sieve or vice versa, but grades uniformly from coarse to fine. Provide a JMF within the specification limits; however, the gradation can exceed the limits when the allowable deviation from the JMF shown in Tables 6 and 7 Tables 4 and 5 are applied.

Table 4. Table 2. Aggregate Gradations	
Sieve Size, inch	Gradation 2 Percent Passing by Mass
1	---
3/4	100
1/2	90-100
3/8	69-89
No. 4	53-73
No. 8	38-60
No. 16	26-48
No. 30	18-38
No. 50	11-27
No. 100	6-18
No. 200	3-6

2.3 ASPHALT CEMENT BINDER

Provide asphalt cement binder that conforms to ASTM D6373 Performance Grade (PG) 64-22. Provide test data indicating grade certification by the supplier at the time of delivery of each load to the mix plant. Submit copies of these certifications to the Government. The supplier is defined as the last source of any modification to the binder. The Government may sample and test the binder at the mix plant at any time before or during mix production.

2.4 MIX DESIGN

Develop the mix design. Perform Job Mix formula (JMF) and aggregates testing no earlier than 6 months before contract award. Provide asphalt mixture composed of well-graded aggregate, mineral filler if required, and asphalt material. Provide aggregate fractions sized, handled in separate size groups, and combined in such proportions that the resulting mixture meets the grading requirements of Table 4 Table 2. Do not produce asphalt pavement for payment acceptance until a JMF has been approved. Design the asphalt mixture using 50 blows with the Marshall hand-held hammer procedures contained in AI MS-2 and the criteria shown in Table 5 Table 3.

Use laboratory compaction temperatures for Polymer Modified Asphalts as recommended by the asphalt binder manufacturer. Determine the Tensile Strength Ratio (TSR) of the composite mixture in accordance with ASTM D4867/D4867M. Compact the TSR specimens to an air void content of 7 percent plus or minus 1 percent. If the Tensile Strength Ratio (TSR) of the composite mixture is less than 75, reject the aggregates or treat the asphalt mixture with an anti-stripping agent. Add a sufficient amount of anti-stripping agent to produce a TSR of not less than 75. If an antistrip agent is required, provide it at no additional cost to the Government. Provide sufficient materials to produce 200 pounds of blended mixture to the Government for verification of mix design at least 14 days prior to construction of test section.

#### 2.4.1 JMF Requirements

Submit the proposed JMF in writing, for approval, at least 14 days prior to the start of the test section including, as a minimum:

- a. Percent passing each sieve size.
- b. Percent of asphalt cement.
- c. Percent of each aggregate and mineral filler to be used.
- d. Asphalt performance grade or penetration grade.
- e. Number of blows of hammer per side of molded specimen.
- f. Laboratory mixing temperature.
- g. Laboratory compaction temperature.
- h. Temperature-viscosity relationship of the asphalt cement
- i. Plot of the combined gradation on the 0.45 power gradation chart, stating the nominal maximum size.
- j. Graphical plots and summary tabulation of Marshall stability, flow, air voids, voids in the mineral aggregate, and unit weight versus asphalt content as shown in AI MS-2. Include summary tabulation that includes individual specimen data for each specimen tested.
- k. Specific gravity and absorption of each aggregate.
- l. Percent natural sand.
- m. Percent particles with two or more fractured faces (in coarse aggregate).
- n. Fine aggregate angularity.
- o. Percent flat or elongated particles in coarse aggregate.
- p. Tensile Strength Ratio and wet/dry specimen test results.
- q. Antistrip agent (if required).
- r. List of all modifiers.
- s. Percentage and properties (asphalt content, aggregate gradation, and aggregate properties) of RAP in accordance with paragraph RECYCLED ASPHALT PAVEMENT, if RAP is used.

Table 5. Table 3. Mix Design Criteria	
Test Property	Marshall (50 Blows)
Stability, pounds, minimum (NA for Superpave)	1000 <sup>(1)</sup>
Flow, 0.01 inch, (NA for Superpave)	8-18
Air voids, percent	3-5
Minimum Percent Voids in Mineral Aggregate (VMA) <sup>(2)</sup>	
Gradation 2	14.0
TSR, minimum percent	75
(1) This is a minimum requirement. Provide significantly higher average during construction to ensure compliance with the specifications.	
(2) Calculate VMA in accordance with AI MS-2, based on ASTM C127 and ASTM C128 bulk specific gravity for the aggregate.	

2.4.2 Adjustments to JMF

The JMF for each mixture is in effect until a new formula is approved in writing by the Government. Should a change in sources of any materials be made, perform a new mix design and a new JMF approved before the new material is used. Make minor adjustments within the specification limits to the JMF to optimize mix volumetric properties. Adjustments to the original JMF are limited to plus or minus 4 percent on the No. 4 and coarser sieves; plus or minus 3 percent on the No. 8 to No. 50 sieves; and plus or minus 1 percent on the No. 100 sieve and No. 200 sieve. Asphalt content adjustments are limited to plus or minus 0.40 from the original JMF. If adjustments are needed that exceed these limits, develop a new mix design.

PART 3 EXECUTION

3.1 CONTRACTOR QUALITY CONTROL

3.1.1 General Quality Control Requirements

Submit the Quality Control Plan. Do not produce hot-mix asphalt for payment acceptance until the quality control plan has been approved. In the quality control plan, address all elements which affect the quality of the pavement including, but not limited to:

- a. Mix Design and unique JMF identification code
- b. Aggregate Grading
- c. Quality of Materials
- d. Stockpile Management and procedures to prevent contamination

- e. Proportioning
- f. Mixing and Transportation
- g. Mixture Volumetrics
- h. Moisture Content of Mixtures
- i. Placing and Compaction
- j. Joints
- k. Surface Smoothness
- l. Truck bed release agent
- m. Correlation of mechanical hammer to hand hammer. Determine the number of blows of the mechanical hammer required to provide the same density of the JMF as provided by the hand hammer. Use the average of three specimens per trial blow application.

### 3.1.2 Testing Laboratory

Provide a fully equipped asphalt laboratory located at the plant or job site that is equipped with heating and air conditioning units to maintain a temperature of 75 plus or minus 5 degrees F. Provide laboratory facilities that are kept clean and all equipment maintained in proper working condition. Provide the Government with unrestricted access to inspect the laboratory facility, to witness quality control activities, and to perform any check testing desired. The Government will advise in writing of any noted deficiencies concerning the laboratory facility, equipment, supplies, or testing personnel and procedures. When the deficiencies are serious enough to adversely affect test results, immediately suspend the incorporation of the materials into the work. Incorporation of the materials into the work will not be permitted to resume until the deficiencies are corrected.

### 3.1.3 Quality Control Testing

Perform all quality control tests applicable to these specifications and as set forth in the Quality Control Program. Use the independent commercial laboratory for acceptance testing in paragraph ACCEPTANCE. Use in-house capabilities or the independent commercial laboratory for quality control testing. Required elements of the testing program include, but are not limited to tests for the control of asphalt content, aggregate gradation, aggregate moisture, moisture in the asphalt mixture, temperatures, VMA, Marshall stability, flow, and in-place density. Develop a Quality Control Testing Plan as part of the Quality Control Program.

#### 3.1.3.1 Asphalt Content

Determine asphalt content a minimum of twice per lot (a lot is defined in paragraph PAVEMENT LOTS) using the ignition method in accordance with ASTM D6307. Use the extraction method in accordance with ASTM D2172/D2172M if the correction factor for the ignition method in ASTM D6307 is greater than 1.0. The asphalt content for the lot will be determined by averaging the test results.

### 3.1.3.2 Aggregate Properties

Determine aggregate gradations a minimum of twice per lot from mechanical analysis of extracted aggregate in accordance with ASTM D5444, ASTM C136/C136M, and ASTM C117. Determine the specific gravity of each aggregate size grouping for each 20,000 tons in accordance with ASTM C127 or ASTM C128. Determine fractured faces for gravel sources for each 20,000 tons in accordance with ASTM D5821. Determine the uncompacted void content of natural sand, manufactured sand, and blended aggregate for each 20,000 tons in accordance with AASHTO T 304 Method A.

### 3.1.3.3 Moisture Content of Aggregate

Determine the moisture content of aggregate used for production a minimum of once per lot in accordance with ASTM C566.

### 3.1.3.4 Moisture Content of Asphalt Mixture

Determine the moisture content of the asphalt mixture at least once per lot in accordance with AASHTO T 329.

### 3.1.3.5 Temperatures

Check temperatures at least four times per lot, at necessary locations to determine the temperature at the dryer, the asphalt cement binder in the storage tank, the asphalt mixture at the plant, and the asphalt mixture at the job site.

### 3.1.3.6 VMA, Marshall Stability, and Flow

Obtain mixture samples at least four times per lot. Calculate the VMA of each specimen in accordance with AI MS-2 based on ASTM C127 and ASTM C128 bulk specific gravity for the aggregate, as well as the Marshall stability and flow, as described in ASTM D6927. Provide VMA within the limits of Table 5 Table 3.

### 3.1.3.7 In-Place Density

Conduct any necessary testing to ensure the specified density is achieved. A nuclear gauge or other non-destructive testing device can be used to monitor pavement density.

### 3.1.3.8 Additional Testing

Perform any additional testing deemed necessary to control the process.

### 3.1.3.9 QC Monitoring

Submit all QC test results to the Government on a daily basis as the tests are performed. The Government reserves the right to monitor any of the Contractor's quality control testing and to perform duplicate testing as a check to the Contractor's quality control testing.

### 3.1.4 Sampling

When directed by the Government, sample and test any material which appears to not meet specification requirements unless such material is voluntarily removed and replaced or deficiencies corrected. Perform all sampling in accordance with standard procedures specified.

### 3.2 PREPARATION OF ASPHALT BINDER MATERIAL

Heat the asphalt cement material while avoiding local overheating. Provide a continuous supply of the asphalt material to the mixer at a uniform temperature. Maintain the temperature of the asphalt delivered to the mixer to provide a suitable viscosity for adequate coating of the aggregate particles. For hot-mix, do not heat unmodified asphalt to a temperature exceeding 325 degrees F when added to the aggregate.

### 3.3 PREPARATION OF MINERAL AGGREGATE

Heat and dry the aggregate prior to mixing. Provide a rate of heating and a maximum temperature that does not damage the aggregates. Do not heat the aggregate to a temperature exceeding 350 degrees F when the asphalt binder is added. Maintain the temperature no lower than is required to obtain complete coating and uniform distribution on the aggregate particles and to provide a mixture of satisfactory workability.

### 3.4 PREPARATION OF ASPHALT MIXTURE

Weigh or meter the aggregates and the asphalt cement and introduce into the mixer the amount specified by the JMF. Mix the combined materials until the aggregate obtains a uniform coating of asphalt binder and is thoroughly distributed throughout the mixture. The moisture content of all asphalt mixture upon discharge from the plant is not to exceed 0.5 percent by total weight of mixture as measured by AASHTO T 329.

### 3.5 PREPARATION OF THE UNDERLYING SURFACE

Immediately before placing the asphalt mixture, clean the underlying course of dust and debris. Apply a prime coat or tack coat in accordance with Section 32 12 13 BITUMINOUS TACK AND PRIME COATS.

### 3.6 TRANSPORTING AND PLACING

#### 3.6.1 Transporting

Transport asphalt mixture from the mixing plant to the site in clean, tight vehicles. Schedule deliveries so that placing and compacting of mixture is uniform with minimum stopping and starting of the paver. Provide adequate artificial lighting for night placements. Hauling over freshly placed material will not be permitted until the material has been compacted as specified, and allowed to cool to 140 degrees F.

#### 3.6.2 Placing

Place the mix in lifts of adequate thickness and compact at a temperature suitable for obtaining density, surface smoothness, and other specified requirements. Upon arrival, place the mixture to the full width by an asphalt paver; strike off in a uniform layer of such depth that, when the work is completed, the required thickness is obtained and the surface conforms to the grade and contour indicated. Do not broadcast waste mixture onto the mat or recycle into the paver hopper. Collect waste mixture and dispose off site. Regulate the speed of the paver to eliminate pulling and tearing of the asphalt mat. Begin placement of the mixture along the centerline of a crowned section or on the high side of areas with a one-way slope. Place the mixture in consecutive adjacent strips having a minimum width of 10 feet. Offset the longitudinal joint



in one course from the longitudinal joint in the course immediately below by at least 1 foot; however, locate the joint in the surface course at the centerline of the pavement. Offset transverse joints in one course by at least 10 feet from transverse joints in the previous course. Offset transverse joints in adjacent lanes a minimum of 10 feet. On isolated areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the mixture can be spread and luted by hand tools.

### 3.7 COMPACTION OF MIXTURE

#### 3.7.1 General

- a. After placing, thoroughly and uniformly compact the mixture by rolling. Compact the surface as soon as possible without causing displacement, cracking, or shoving. Determine the sequence of rolling operations and the type of rollers used with the exception that application of more than three passes with a vibratory roller in the vibrating mode is prohibited. Maintain the speed of the roller, at all times, sufficiently slow to avoid displacement of the asphalt mixture and to be effective in compaction. Correct at once any displacement occurring as a result of reversing the direction of the roller, or from any other cause.
- b. Furnish sufficient rollers to handle the output of the plant. Continue rolling until the surface is of uniform texture, true to grade and cross section, and the required field density is obtained. To prevent adhesion of the mixture to the roller, keep the wheels properly moistened, but excessive water is not permitted. In areas not accessible to the roller, thoroughly compact the mixture with hand tampers or small compactors. Remove the full depth of any mixture that becomes loose and broken, mixed with dirt, contains check-cracking, or is in any way defective. Replace with fresh asphalt mixture and immediately compact to conform to the surrounding area. Perform this work at no expense to the Government. Skin patching is not allowed.

#### 3.7.2 Segregation

The Government can sample and test any material that looks deficient. When the in-place material appears to be segregated, the Government has the option to sample the material and have it tested and compared to the in-place density requirements in Table 2 paragraph ACCEPTANCE. If the material fails to meet these specification requirements, remove and replace the extent of the segregated material the full depth of the layer of asphalt mixture at no additional cost to the Government. When segregation occurs in the mat, take appropriate action to correct the process so that additional segregation does not occur.

### 3.8 JOINTS

Construct joints to ensure a continuous bond between the courses and to obtain the required density. Provide all joints with the same texture as other sections of the course and meet the requirements for smoothness and grade.

#### 3.8.1 Transverse Joints

Do not pass the roller over the unprotected end of the freshly laid

mixture, except when necessary to form a transverse joint. When necessary to form a transverse joint, construct by means of placing a bulkhead or by tapering the course. Utilize a dry saw cut on the transverse joint full depth and width on a straight line to expose a vertical face prior to placing the adjacent lane. Remove the cutback material from the project. In both methods, provide a light tack coat of asphalt material to all contact surfaces before placing any fresh mixture against the joint.

### 3.8.2 Longitudinal Joints

Provide a joint that meets density and smoothness requirements for joints and has uniform texture. Cut back longitudinal joints which are irregular, damaged, uncompacted, cold (less than 175 degrees F at the time of placing adjacent lanes), or otherwise defective, a maximum of 3 inches from the top of the course with a cutting wheel to expose a clean, sound, near vertical surface for the full depth of the course. Remove all cutback material from the project. Provide a light tack coat of asphalt material to all contact surfaces prior to placing any fresh mixture against the joint.

-- End of Section --



SECTION 32 12 16

HOT-MIX ASPHALT (HMA) FOR ROADS  
08/09

PART 1 GENERAL

1.1 UNIT PRICES

1.1.1 Method of Measurement

The amount paid for will be the number of short tons of hot-mix asphalt mixture used in the accepted work. Weigh hot-mix asphalt mixture after mixing, and no separate payment will be made for weight of asphalt cement material incorporated herein.

1.1.2 Basis of Payment

Quantities of hot-mix asphalt mixtures, determined as specified above, will be paid for at respective contract unit prices or at reduced prices adjusted in accordance with paragraphs MATERIAL ACCEPTANCE and PERCENT PAYMENT. Payment will constitute full compensation for furnishing all materials, equipment, plant, and tools; and for all labor and other incidentals necessary to complete work required by this section of the specification.

1.1.3 Percent Payment

Submit pay calculations. When a lot of material fails to meet the specification requirements for 100 percent pay, as outlined in the following paragraphs, that lot shall be removed and replaced, or accepted at a reduced price which will be computed by multiplying the unit price by the lot's pay factor. The lot pay factor is determined by taking the lowest computed pay factor based on either laboratory air voids, in-place density, grade or smoothness (each discussed below). At the end of the project, an average of all lot pay factors will be calculated. If this average lot pay factor equals or exceeds 95.0 percent, and no individual lot has a pay factor less than 75.1 percent, then the percent payment for the entire project will be 100 percent of the unit bid price. If the average lot pay factor is less than 95.0 percent, then each lot will be paid for at the unit price multiplied by the lot's pay factor. For any lots which are less than 2000 short tons, a weighted lot pay factor will be used to calculate the average lot pay factor.

1.1.4 Laboratory Air Voids and Theoretical Maximum Density

Laboratory air voids will be calculated by determining the Marshall or Superpave density of each lab compacted specimen using the laboratory-prepared, thoroughly dry method of ASTM D2726/D2726M and determining the theoretical maximum density of every other subplot sample using ASTM D2041/D2041M. Laboratory air void calculations for each subplot will use the latest theoretical maximum density values obtained, either for that subplot or the previous subplot. The mean absolute deviation of the four laboratory air void contents (one from each subplot) from the JMF air void content will be evaluated and a pay factor determined from Table 1. All laboratory air void tests will be completed and reported within 24 hours after completion of construction of each lot.

1.1.5 Mean Absolute Deviation

An example of the computation of mean absolute deviation for laboratory air voids is as follows: Assume that the laboratory air voids are determined from 4 random samples of a lot (where 3 specimens were compacted from each sample). The average laboratory air voids for each subplot sample are determined to be 3.5, 3.0, 4.0, and 3.7. Assume that the target air voids from the JMF is 4.0. The mean absolute deviation is then:

$$\text{Mean Absolute Deviation} = (|3.5 - 4.0| + |3.0 - 4.0| + |4.0 - 4.0| + |3.7 - 4.0|) / 4$$

$$= (0.5 + 1.0 + 0.0 + 0.3) / 4 = (1.8) / 4 = 0.45$$

The mean absolute deviation for laboratory air voids is determined to be 0.45. It can be seen from Table 1 that the lot's pay factor based on laboratory air voids, is 100 percent.

Table 1. Pay Factor Based on Laboratory Air Voids	
Mean Absolute Deviation of Lab Air Voids from JMF	Pay Factor, percent
0.60 or less	100
0.61 - 0.80	98
0.81 - 1.00	95
1.01 - 1.20	90
Above 1.20	reject (0)

1.1.6 In-place Density

For determining in-place density, one random core (4 inches or 6 inches in diameter) will be taken by the Government from the mat (interior of the lane) of each subplot, and one random core will be taken from the joint (immediately over joint) of each subplot. Each random core will be full thickness of the layer being placed. When the random core is less than 1 inch thick, it will not be included in the analysis. In this case, another random core will be taken. After air drying to a constant weight, cores obtained from the mat and from the joints will be used for in-place density determination.

1.1.7 Mat and Joint Densities

The average in-place mat and joint densities are expressed as a percentage of the average TMD for the lot. The TMD for each lot will be determined as the average TMD of the two random samples per lot. The average in-place mat density and joint density for a lot are determined and compared with Table 2 to calculate a single pay factor per lot based on in-place density, as described below. First, a pay factor for both mat density and joint density are determined from Table 2. The area associated with the joint is then determined and will be considered to be 5

-feet wide times the length of completed longitudinal construction joint in the lot. This area will not exceed the total lot size. The length of joint to be considered will be that length where a new lane has been placed against an adjacent lane of hot-mix asphalt pavement, either an adjacent freshly paved lane or one paved at any time previously. The area associated with the joint is expressed as a percentage of the total lot area. A weighted pay factor for the joint is determined based on this percentage (see example below). The pay factor for mat density and the weighted pay factor for joint density is compared and the lowest selected. This selected pay factor is the pay factor based on density for the lot. When the TMD on both sides of a longitudinal joint is different, the average of these two TMD will be used as the TMD needed to calculate the percent joint density. All density results for a lot will be completed and reported within 24 hours after the construction of that lot.

Table 2. Pay Factor Based on In-place Density		
Average Mat Density (4 Cores) (Percent of TMD)	Pay Factor, Percent	Average Joint Density (4 Cores) (Percent of TMD)
94.0 - 96.0	100.0	92.5 or above
93.9	100.0	92.4
93.8 or 96.1	99.9	92.3
93.7	99.8	92.2
93.6 or 96.2	99.6	92.1
93.5	99.4	92.0
93.4 or 96.3	99.1	91.9
93.3	98.7	91.8
93.2 or 96.4	98.3	91.7
93.1	97.8	91.6
93.0 or 96.5	97.3	91.5
92.9	96.3	91.4
92.8 or 96.6	94.1	91.3
92.7	92.2	91.2
92.6 or 96.7	90.3	91.1
92.5	87.9	91.0
92.4 or 96.8	85.7	90.9

Table 2. Pay Factor Based on In-place Density		
Average Mat Density (4 Cores) (Percent of TMD)	Pay Factor, Percent	Average Joint Density (4 Cores) (Percent of TMD)
92.3	83.3	90.8
92.2 or 96.9	80.6	90.7
92.1	78.0	90.6
92.0 or 97.0	75.0	90.5
below 92.0 or above 97.0	0.0 (reject)	below 90.5

1.1.1.8 Pay Factor Based on In-place Density

An example of the computation of a pay factor (in I-P units only) based on in-place density, is as follows: Assume the following test results for field density made on the lot: (1) Average mat density = 93.2 percent of TMD. (2) Average joint density = 91.5 percent of TMD. (3) Total area of lot = 30,000 square feet. (4) Length of completed longitudinal construction joint = 2000 feet.

1.1.1.8.1 Step 1

Determine pay factor based on mat density and on joint density, using Table 2:

Mat Density	93.2 percent	equals	98.3 pay factor
Joint Density	91.5 percent	equals	97.3 pay factor

1.1.1.8.2 Step 2

Determine ratio of joint area (length of longitudinal joint x 5 ft) to mat area (total paved area in the lot): Multiply the length of completed longitudinal construction joint by the specified 5 ft. width and divide by the mat area (total paved area in the lot).

(2000 ft. x 5 ft.)/30,000 sq.ft. = 0.3333 ratio of joint area to mat area (ratio).

1.1.1.8.3 Step 3

Weighted pay factor (wpf) for joint is determined as indicated below:

$$\text{wpf} = \text{joint pay factor} + (100 - \text{joint pay factor}) (1 - \text{ratio})$$

$$\text{wpf} = 97.3 + (100 - 97.3) (1 - 0.3333) = 99.1 \text{ percent}$$

1.1.1.8.4 Step 4

Compare weighted pay factor for joint density to pay factor for mat density and select the smaller:

- a. Pay factor for mat density: 98.3 percent. Weighted pay factor for joint density: 99.1 percent
- b. Select the smaller of the two values as pay factor based on density: 98.3 percent

#### 1.1.9 Pay Factor for Grade

When more than 5 percent of all measurements made within a lot are outside the 0.05-foot tolerance, the pay factor based on grade for that lot will be 95 percent. In areas where the grade exceeds the tolerance by more than 50 percent, remove the surface lift full depth and replace the lift with hot-mix asphalt to meet specification requirements, at no additional cost to the Government.

#### 1.1.10 Payment Adjustment for Smoothness

##### 1.1.10.1 Straightedge Testing

Record location and deviation from straightedge for all measurements. When between 5.0 and 10.0 percent of all measurements made within a lot exceed the tolerance specified in paragraph Smoothness Requirements above, after any reduction of high spots or removal and replacement, the computed pay factor for that lot based on surface smoothness, will be 95 percent. When more than 10.0 percent of all measurements exceed the tolerance, the computed pay factor will be 90 percent. When between 15.0 and 20.0 percent of all measurements exceed the tolerance, the computed pay factor will be 75 percent. When 20.0 percent or more of the measurements exceed the tolerance, the lot shall be removed and replaced at no additional cost to the Government. Regardless of the above, any small individual area with surface deviation which exceeds the tolerance given above by more than 50 percent, shall be corrected by diamond grinding to meet the specification requirements above or shall be removed and replaced at no additional cost to the Government.

#### 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 156	(2013; R 2017) Standard Specification for Requirements for Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures
AASHTO M 320	(2017) Standard Specification for Performance-Graded Asphalt Binder
AASHTO T 304	(2011; R 2015) Standard Method of Test for Uncompacted Void Content of Fine Aggregate

ASPHALT INSTITUTE (AI)

AI MS-2	(2015) Asphalt Mix Design Methods
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ASTM INTERNATIONAL (ASTM)

ASTM C29/C29M	(2017a) Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
ASTM C88	(2018) Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM C117	(2023) Standard Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C127	(2015) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
ASTM C128	(2015) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
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 C142/C142M	(2017) Standard Test Method for Clay Lumps and Friable Particles in Aggregates
ASTM C566	(2013) Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
ASTM D140/D140M	(2016) Standard Practice for Sampling Asphalt Materials
ASTM D242/D242M	(2009; R 2014) Mineral Filler for Bituminous Paving Mixtures
ASTM D1461	(2017) Standard Test Method for Moisture or Volatile Distillates in Asphalt Mixtures
ASTM D2041/D2041M	(2011) Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
ASTM D2172/D2172M	(2017; E 2018) Standard Test Methods for Quantitative Extraction of Asphalt Binder from Asphalt Mixtures
ASTM D2419	(2014) Sand Equivalent Value of Soils and Fine Aggregate
ASTM D2489/D2489M	(2016) Standard Test Method for Estimating

	Degree of Particle Coating of Asphalt Mixtures
ASTM D2726/D2726M	(2019) Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures
ASTM D2950/D2950M	(2014) Density of Bituminous Concrete in Place by Nuclear Methods
ASTM D3665	(2012; R 2017) Standard Practice for Random Sampling of Construction Materials
ASTM D3666	(2016) Standard Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials
ASTM D4125/D4125M	(2010) Asphalt Content of Bituminous Mixtures by the Nuclear Method
ASTM D4791	(2019) Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
ASTM D4867/D4867M	(2009; R 2014) Effect of Moisture on Asphalt Concrete Paving Mixtures
ASTM D5444	(2015) Mechanical Size Analysis of Extracted Aggregate
ASTM D6307	(2019) Standard Test Method for Asphalt Content of Asphalt Mixture by Ignition Method
ASTM D6925	(2014) Standard Test Method for Preparation and Determination of the Relative Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor
ASTM D6926	(2020) Standard Practice for Preparation of Asphalt Mixture Specimens Using Marshall Apparatus
ASTM D6927	(2015) Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures

U.S. ARMY CORPS OF ENGINEERS (USACE)

COE CRD-C 171	(1995) Standard Test Method for Determining Percentage of Crushed Particles in Aggregate
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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-03 Product Data

Mix Design; G

Quality Control; G

Material Acceptance; G

Percent Payment; G

SD-04 Samples

Asphalt Cement Binder

Aggregates

SD-06 Test Reports

Aggregates; G

QC Monitoring

SD-07 Certificates

Asphalt Cement Binder; G

Testing Laboratory

1.4 ENVIRONMENTAL REQUIREMENTS

Do not place the hot-mix asphalt upon a wet surface or when the surface temperature of the underlying course is less than specified in Table 3. The temperature requirements may be waived by the Contracting Officer, if requested; however, meet all other requirements, including compaction.

Table 3. Surface Temperature Limitations of Underlying Course	
Mat Thickness, inches	Degrees F
3 or greater	40
Less than 3	45

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

Perform the work consisting of pavement courses composed of mineral aggregate and asphalt material heated and mixed in a central mixing plant and placed on a prepared course. HMA designed and constructed in accordance with this section shall conform to the lines, grades, thicknesses, and typical cross sections indicated. Construct each course to the depth, section, or elevation required by the drawings and roll,

finish, and approve it before the placement of the next course.

#### 2.1.1 Asphalt Mixing Plant

Plants used for the preparation of hot-mix asphalt shall conform to the requirements of AASHTO M 156 with the following changes:

##### 2.1.1.1 Truck Scales

Weigh the asphalt mixture on approved, certified scales at the Contractor's expense. Inspect and seal scales at least annually by an approved calibration laboratory.

##### 2.1.1.2 Testing Facilities

Provide laboratory facilities at the plant for the use of the Government's acceptance testing and the Contractor's quality control testing.

##### 2.1.1.3 Inspection of Plant

Provide the Contracting Officer with access at all times, to all areas of the plant for checking adequacy of equipment; inspecting operation of the plant; verifying weights, proportions, and material properties; checking the temperatures maintained in the preparation of the mixtures and for taking samples. Provide assistance as requested, for the Government to procure any desired samples.

##### 2.1.1.4 Storage bins

Use of storage bins for temporary storage of hot-mix asphalt will be permitted as follows:

- a. The asphalt mixture may be stored in non-insulated storage bins for a period of time not exceeding 3 hours.
- b. The asphalt mixture may be stored in insulated storage bins for a period of time not exceeding 8 hours. The mix drawn from bins shall meet the same requirements as mix loaded directly into trucks.

#### 2.1.2 Hauling Equipment

Provide trucks for hauling hot-mix asphalt having tight, clean, and smooth metal beds. To prevent the mixture from adhering to them, the truck beds shall be lightly coated with a minimum amount of paraffin oil, lime solution, or other approved material. Petroleum based products shall not be used as a release agent. Each truck shall have a suitable cover to protect the mixture from adverse weather. When necessary to ensure that the mixture will be delivered to the site at the specified temperature, truck beds shall be insulated or heated and covers (tarps) shall be securely fastened.

#### 2.1.3 Asphalt Pavers

Provide asphalt pavers which are self-propelled, with an activated screed, heated as necessary, and capable of spreading and finishing courses of hot-mix asphalt which will meet the specified thickness, smoothness, and grade. The paver shall have sufficient power to propel itself and the hauling equipment without adversely affecting the finished surface.

#### 2.1.3.1 Receiving Hopper

Provide paver with a receiving hopper of sufficient capacity to permit a uniform spreading operation and equipped with a distribution system to place the mixture uniformly in front of the screed without segregation. The screed shall effectively produce a finished surface of the required evenness and texture without tearing, shoving, or gouging the mixture.

#### 2.1.3.2 Automatic Grade Controls

Equip the paver with a control system capable of automatically maintaining the specified screed elevation. The control system shall be automatically actuated from either a reference line and/or through a system of mechanical sensors or sensor-directed mechanisms or devices which will maintain the paver screed at a predetermined transverse slope and at the proper elevation to obtain the required surface. The transverse slope controller shall be capable of maintaining the screed at the desired slope within plus or minus 0.1 percent. A transverse slope controller shall not be used to control grade. Provide controls capable of working in conjunction with any of the following attachments:

- a. Ski-type device of not less than 30 feet in length.
- b. Taut stringline set to grade.
- c. Short ski or shoe for joint matching.
- d. Laser control.

#### 2.1.4 Rollers

Rollers shall be in good condition and shall be operated at slow speeds to avoid displacement of the asphalt mixture. The number, type, and weight of rollers shall be sufficient to compact the mixture to the required density while it is still in a workable condition. Do not use equipment which causes excessive crushing of the aggregate.

### 2.2 AGGREGATES

Provide aggregates consisting of crushed stone, crushed gravel, crushed slag, screenings, natural sand and mineral filler, as required. Submit sufficient materials to produce 200 lb of blended mixture for mix design verification. The portion of material retained on the No. 4 sieve is coarse aggregate. The portion of material passing the No. 4 sieve and retained on the No. 200 sieve is fine aggregate. The portion passing the No. 200 sieve is defined as mineral filler. Submit all aggregate test results and samples to the Contracting Officer at least 14 days prior to start of construction.

#### 2.2.1 Coarse Aggregate

Provide coarse aggregate consisting of sound, tough, durable particles, free from films of material that would prevent thorough coating and bonding with the asphalt material and free from organic matter and other deleterious substances. All individual coarse aggregate sources shall meet the following requirements:

- a. The percentage of loss shall not be greater than 40 percent after 500 revolutions when tested in accordance with ASTM C131/C131M.

- b. The percentage of loss shall not be greater than 18 percent after five cycles when tested in accordance with ASTM C88 using magnesium sulfate or 12 percent when using sodium sulfate.
- c. At least 75 percent by weight of coarse aggregate shall have at least two or more fractured faces when tested in accordance with COE CRD-C 171. Fractured faces shall be produced by crushing.
- d. The particle shape shall be essentially cubical and the aggregate shall not contain more than 20 percent, by weight, of flat and elongated particles (3:1 ratio of maximum to minimum) when tested in accordance with ASTM D4791.
- e. Slag shall be air-cooled, blast furnace slag, with a compacted weight of not less than 75 lb/cu ft when tested in accordance with ASTM C29/C29M.
- f. Clay lumps and friable particles shall not exceed 0.3 percent, by weight, when tested in accordance with ASTM C142/C142M.

#### 2.2.2 Fine Aggregate

Fine aggregate shall consist of clean, sound, tough, durable particles free from coatings of clay, silt, or any objectionable material and containing no clay balls.

- a. All individual fine aggregate sources shall have a sand equivalent value not less than 45 when tested in accordance with ASTM D2419.
- b. The fine aggregate portion of the blended aggregate shall have an uncompacted void content not less than 45.0 percent when tested in accordance with AASHTO T 304 Method A.
- c. The quantity of natural sand (noncrushed material) added to the aggregate blend shall not exceed 25 percent by weight of total aggregate.
- d. Clay lumps and friable particles shall not exceed 0.3 percent, by weight, when tested in accordance with ASTM C142/C142M

#### 2.2.3 Mineral Filler

Mineral filler shall be nonplastic material meeting the requirements of ASTM D242/D242M.

#### 2.2.4 Aggregate Gradation

The combined aggregate gradation shall conform to gradations specified in Table 4, when tested in accordance with ASTM C136/C136M and ASTM C117, and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve or vice versa, but grade uniformly from coarse to fine.

Table 4. Aggregate Gradations	
Sieve Size, inch	Gradation 2 Percent Passing by Mass
1	---
3/4	100
1/2	76-96
3/8	69-89
No. 4	53-73
No. 8	38-60
No. 16	26-48
No. 30	18-38
No. 50	11-27
No. 100	6-18
No. 200	3-6

2.3 ASPHALT CEMENT BINDER

Submit a 5 gallon sample for mix design verification. Asphalt cement binder shall conform to AASHTO M 320 Performance Grade (PG) 64-22. Test data indicating grade certification shall be provided by the supplier at the time of delivery of each load to the mix plant. Submit copies of these certifications to the Contracting Officer. The supplier is defined as the last source of any modification to the binder. The Contracting Officer may sample and test the binder at the mix plant at any time before or during mix production. Obtain samples for this verification testing in accordance with ASTM D140/D140M and in the presence of the Contracting Officer. Furnish these samples to the Contracting Officer for the verification testing, which shall be at no cost to the Contractor. Submit samples of the asphalt cement specified for approval not less than 14 days before start of the test section. Submit copies of certified test data, amount, type and description of any modifiers blended into the asphalt cement binder.

2.4 MIX DESIGN

- a. Develop the mix design. The asphalt mix shall be composed of a mixture of well-graded aggregate, mineral filler if required, and asphalt material. The aggregate fractions shall be sized, handled in separate size groups, and combined in such proportions that the resulting mixture meets the grading requirements of the job mix formula (JMF). Submit proposed JMF; do not produce hot-mix asphalt for payment until a JMF has been approved. The hot-mix asphalt shall

be designed in accordance with Marshall (MS-02), Superpave (SP-2), or Hveem (MS-02) procedures and the criteria shown in Table 5. Use the hand-held hammer to compact the specimens for Marshall mix design. If the Tensile Strength Ratio (TSR) of the composite mixture, as determined by ASTM D4867/D4867M is less than 75, the aggregates shall be rejected or the asphalt mixture treated with an approved anti-stripping agent. The amount of anti-stripping agent added shall be sufficient to produce a TSR of not less than 75. Provide an antistrip agent, if required, at no additional cost. Sufficient materials to produce 200 pounds of blended mixture shall be provided to the Contracting Officer for verification of mix design at least 14 days prior to construction of test section.

#### 2.4.1 JMF Requirements

Submit in writing the job mix formula for approval at least 14 days prior to the start of the test section including as a minimum:

- a. Percent passing each sieve size.
- b. Percent of asphalt cement.
- c. Percent of each aggregate and mineral filler to be used.
- d. Asphalt viscosity grade, penetration grade, or performance grade.
- e. Number of blows of hand-held hammer per side of molded specimen. (NA for Superpave)
- f. Number of gyrations of Superpave gyratory compactor, (NA for Marshall mix design)
- g. Laboratory mixing temperature.
- h. Lab compaction temperature.
- i. Temperature-viscosity relationship of the asphalt cement.
- j. Plot of the combined gradation on the 0.45 power gradation chart, stating the nominal maximum size.
- k. Graphical plots of stability, flow, air voids, voids in the mineral aggregate, and unit weight versus asphalt content as shown in AI MS-2.
- l. Specific gravity and absorption of each aggregate.
- m. Percent natural sand.
- n. Percent particles with 2 or more fractured faces (in coarse aggregate).
- o. Fine aggregate angularity.
- p. Percent flat or elongated particles (in coarse aggregate).
- q. Tensile Strength Ratio(TSR).
- r. Antistrip agent (if required) and amount.
- s. List of all modifiers and amount.



Table 4. Aggregate Gradations	
Sieve Size, inch	Gradation 2 Percent Passing by Mass
1	-
3/4	100
1/2	76-96
3/8	69-89
No. 4	53-73
No. 8	38-60
No. 16	26-78
No. 30	18-38
No. 50	11-27
No. 100	6-18
No. 200	3-6

Table 5. Mix Design Criteria	
Test Property	50 Blows or Mix Gyration
Stability, pounds, minimum (NA for Superpave)	*1000
Flow, 0.01 inch, (NA for Superpave)	8-18
Air voids, percent	3-5
Percent Voids in mineral aggregate (VMA), (minimum)	
Gradation 1	13.0
Gradation 2	14.0
Gradation 3	15.0
TSR, minimum percent	75

Table 5. Mix Design Criteria	
Test Property	50 Blows or Mix Gyration
* This is a minimum requirement. The average during construction shall be significantly higher than this number to ensure compliance with the specifications.	
** Calculate VMA in accordance with AI MS-2, based on ASTM C127 and ASTM C128 bulk specific gravity for the aggregate.	

2.4.2 Adjustments to Field JMF

Keep the Laboratory JMF for each mixture in effect until a new formula is approved in writing by the Contracting Officer. Should a change in sources of any materials be made, perform a new laboratory JMF design and a new JMF approved before the new material is used. The Contractor will be allowed to adjust the Laboratory JMF within the limits specified below to optimize mix volumetric properties with the approval of the Contracting Officer. Adjustments to the Laboratory JMF shall be applied to the field (plant) established JMF and limited to those values as shown. Adjustments shall be targeted to produce or nearly produce 4 percent voids total mix (VTM).

TABLE 6. Field (Plant) Established JMF Tolerances	
Sieves	Adjustments (plus or minus), percent
1/2 inch	3
No. 4	3
No. 8	3
No. 200	1
Binder Content	0.4

Table 4. Aggregate Gradations	
Sieve Size, inch	Gradation 2 Percent Passing by Mass
1	-
3/4	100
1/2	76-96
3/8	69-89

Table 4. Aggregate Gradations	
No. 4	53-73
No. 8	38-60
No. 16	26-78
No. 30	18-38
No. 50	11-27
No. 100	6-18
No. 200	3-6

If adjustments are needed that exceed these limits, develop a new mix design. Tolerances given above may permit the aggregate grading to be outside the limits shown in Table 4; while not desirable, this is acceptable, except for the No. 200 sieve, which shall remain within the aggregate grading of Table 4.

PART 3 EXECUTION

3.1 PREPARATION OF ASPHALT BINDER MATERIAL

Heat the asphalt cement material avoiding local overheating and providing a continuous supply of the asphalt material to the mixer at a uniform temperature. The temperature of unmodified asphalts shall be no more than 325 degrees F when added to the aggregates. Performance-Graded (PG) asphalts shall be within the temperature range of 265-320 degrees F when added to the aggregate.

3.2 PREPARATION OF MINERAL AGGREGATE

Heat and dry the aggregate for the mixture prior to mixing. No damage shall occur to the aggregates due to the maximum temperature and rate of heating used. The temperature of the aggregate and mineral filler shall not exceed 350 degrees F when the asphalt cement is added. The temperature shall not be lower than is required to obtain complete coating and uniform distribution on the aggregate particles and to provide a mixture of satisfactory workability.

3.3 PREPARATION OF HOT-MIX ASPHALT MIXTURE

The aggregates and the asphalt cement shall be weighed or metered and introduced into the mixer in the amount specified by the JMF. Mix the combined materials until the aggregate obtains a uniform coating of asphalt binder and is thoroughly distributed throughout the mixture. Wet mixing time shall be the shortest time that will produce a satisfactory mixture, but no less than 25 seconds for batch plants. Establish the wet mixing time for all plants based on the procedure for determining the percentage of coated particles described in ASTM D2489/D2489M, for each individual plant and for each type of aggregate used. The wet mixing time will be set to at least achieve 95 percent of coated particles. The moisture content of all hot-mix asphalt upon discharge from the plant

shall not exceed 0.5 percent by total weight of mixture as measured by ASTM D1461.

### 3.4 PREPARATION OF THE UNDERLYING SURFACE

Immediately before placing the hot mix asphalt, clean the underlying course of dust and debris. Apply a prime coat in accordance with the contract specifications.

### 3.5 TEST SECTION

A test section will not be required.

### 3.6 TESTING LABORATORY

Submit certification of compliance and Plant Scale Calibration Certification. Use a laboratory to develop the JMF that meets the requirements of ASTM D3666. The Government will inspect the laboratory equipment and test procedures prior to the start of hot mix operations for conformance to ASTM D3666. The laboratory shall maintain the Corps certification for the duration of the project. A statement signed by the manager of the laboratory stating that it meets these requirements or clearly listing all deficiencies shall be submitted to the Contracting Officer prior to the start of construction. The statement shall contain as a minimum:

- a. Qualifications of personnel; laboratory manager, supervising technician, and testing technicians.
- b. A listing of equipment to be used in developing the job mix.
- c. A copy of the laboratory's quality control system.
- d. Evidence of participation in the AASHTO Materials Reference Laboratory (AMRL) program.

### 3.7 TRANSPORTING AND PLACING

#### 3.7.1 Transporting

Transport the hot-mix asphalt from the mixing plant to the site in clean, tight vehicles. Schedule deliveries so that placing and compacting of mixture is uniform with minimum stopping and starting of the paver. Provide adequate artificial lighting for night placements. Hauling over freshly placed material will not be permitted until the material has been compacted as specified, and allowed to cool to 140 degrees F.

#### 3.7.2 Placing

Place and compact the mix at a temperature suitable for obtaining density, surface smoothness, and other specified requirements. Upon arrival, place the mixture to the full width by an asphalt paver; it shall be struck off in a uniform layer of such depth that, when the work is completed, it will have the required thickness and conform to the grade and contour indicated. Regulate the speed of the paver to eliminate pulling and tearing of the asphalt mat. Unless otherwise permitted, placement of the mixture shall begin along the centerline of a crowned section or on the high side of areas with a one-way slope. Place the mixture in consecutive adjacent strips having a minimum width of 10 feet. The longitudinal joint

in one course shall offset the longitudinal joint in the course immediately below by at least 1 foot; however, the joint in the surface course shall be at the centerline of the pavement. Transverse joints in one course shall be offset by at least 10 feet from transverse joints in the previous course. Transverse joints in adjacent lanes shall be offset a minimum of 10 feet. On isolated areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the mixture may be spread and luted by hand tools.

### 3.8 COMPACTION OF MIXTURE

After placing, the mixture shall be thoroughly and uniformly compacted by rolling. Compact the surface as soon as possible without causing displacement, cracking or shoving. The sequence of rolling operations and the type of rollers used shall be at the discretion of the Contractor. The speed of the roller shall, at all times, be sufficiently slow to avoid displacement of the hot mixture and be effective in compaction. Any displacement occurring as a result of reversing the direction of the roller, or from any other cause, shall be corrected at once. Furnish sufficient rollers to handle the output of the plant. Continue rolling until the surface is of uniform texture, true to grade and cross section, and the required field density is obtained. To prevent adhesion of the mixture to the roller, keep the wheels properly moistened but excessive water will not be permitted. In areas not accessible to the roller, the mixture shall be thoroughly compacted with hand tampers. Any mixture that becomes loose and broken, mixed with dirt, contains check-cracking, or is in any way defective shall be removed full depth, replaced with fresh hot mixture and immediately compacted to conform to the surrounding area. This work shall be done at the Contractor's expense. Skin patching will not be allowed.

### 3.9 JOINTS

The formation of joints shall be performed ensuring a continuous bond between the courses and to obtain the required density. All joints shall have the same texture as other sections of the course and meet the requirements for smoothness and grade.

#### 3.9.1 Transverse Joints

Do not pass the roller over the unprotected end of the freshly laid mixture, except when necessary to form a transverse joint. When necessary to form a transverse joint, it shall be made by means of placing a bulkhead or by tapering the course. The tapered edge shall be cut back to its full depth and width on a straight line to expose a vertical face prior to placing material at the joint. Remove the cutback material from the project. In both methods, all contact surfaces shall be given a light tack coat of asphalt material before placing any fresh mixture against the joint.

#### 3.9.2 Longitudinal Joints

Longitudinal joints which are irregular, damaged, uncompacted, cold (less than 175 degrees F at the time of placing adjacent lanes), or otherwise defective, shall be cut back a maximum of 3 inches from the top of the course with a cutting wheel to expose a clean, sound vertical surface for the full depth of the course. All cutback material shall be removed from the project. All contact surfaces shall be given a light tack coat of asphalt material prior to placing any fresh mixture against the joint.

The Contractor will be allowed to use an alternate method if it can be demonstrated that density, smoothness, and texture can be met.

### 3.10 QUALITY CONTROL

#### 3.10.1 General Quality Control Requirements

Develop and submit an approved Quality Control Plan. Submit aggregate and QC test results. Do not produce hot-mix asphalt for payment until the quality control plan has been approved addressing all elements which affect the quality of the pavement including, but not limited to:

- a. Mix Design
- b. Aggregate Grading
- c. Quality of Materials
- d. Stockpile Management
- e. Proportioning
- f. Mixing and Transportation
- g. Mixture Volumetrics
- h. Moisture Content of Mixtures
- i. Placing and Finishing
- j. Joints
- k. Compaction
- l. Surface Smoothness

#### 3.10.2 Quality Control Testing

Perform all quality control tests applicable to these specifications and as set forth in the Quality Control Program. The testing program shall include, but shall not be limited to, tests for the control of asphalt content, aggregate gradation, temperatures, aggregate moisture, moisture in the asphalt mixture, laboratory air voids, stability, flow, in-place density, grade and smoothness. Develop a Quality Control Testing Plan as part of the Quality Control Program.

##### 3.10.2.1 Asphalt Content

A minimum of two tests to determine asphalt content will be performed per lot (a lot is defined in paragraph MATERIAL ACCEPTANCE and PERCENT PAYMENT) by one of the following methods: the extraction method in accordance with ASTM D2172/D2172M, Method A or B, the ignition method in accordance with ASTM D6307, or the nuclear method in accordance with ASTM D4125/D4125M. Calibrate the ignition oven or the nuclear gauge for the specific mix being used. For the extraction method, determine the weight of ash, as described in ASTM D2172/D2172M, as part of the first extraction test performed at the beginning of plant production; and as part of every tenth extraction test performed thereafter, for the duration of plant production. The last weight of ash value obtained shall be used

in the calculation of the asphalt content for the mixture.

#### 3.10.2.2 Gradation

Determine aggregate gradations a minimum of twice per lot from mechanical analysis of recovered aggregate in accordance with ASTM D5444. When asphalt content is determined by the ignition oven or nuclear method, aggregate gradation shall be determined from hot bin samples on batch plants, or from the cold feed on drum mix plants. For batch plants, test aggregates in accordance with ASTM C136/C136M using actual batch weights to determine the combined aggregate gradation of the mixture.

#### 3.10.2.3 Temperatures

Check temperatures at least four times per lot, at necessary locations, to determine the temperature at the dryer, the asphalt cement in the storage tank, the asphalt mixture at the plant, and the asphalt mixture at the job site.

#### 3.10.2.4 Aggregate Moisture

Determine the moisture content of aggregate used for production a minimum of once per lot in accordance with ASTM C566.

#### 3.10.2.5 Moisture Content of Mixture

Determine the moisture content of the mixture at least once per lot in accordance with ASTM D1461 or an approved alternate procedure.

#### 3.10.2.6 Laboratory Air Voids, Marshall Stability and Flow

Take mixture samples at least four times per lot compacted into specimens, using 50 blows per side with the hand-held Marshall hammer as described in ASTM D6926. When the Superpave gyratory compactor is used, mixes will be compacted to 50 gyrations in accordance with ASTM D6925. Hot-mix provided under the DOT Superpave option shall be compacted in accordance with the DOT requirements. After compaction, determine the laboratory air voids of each specimen. Stability and flow shall be determined for the Marshall-compacted specimens, in accordance with ASTM D6927.

#### 3.10.2.7 In-Place Density

Conduct any necessary testing to ensure the specified density is achieved. A nuclear gauge may be used to monitor pavement density in accordance with ASTM D2950/D2950M.

#### 3.10.2.8 Grade and Smoothness

Conduct the necessary checks to ensure the grade and smoothness requirements are met in accordance with paragraphs MATERIAL ACCEPTANCE and PERCENT PAYMENT.

#### 3.10.2.9 Additional Testing

Any additional testing, which the Contractor deems necessary to control the process, may be performed at the Contractor's option.

#### 3.10.2.10 QC Monitoring

Submit all QC test results to the Contracting Officer on a daily basis as the tests are performed. The Contracting Officer reserves the right to monitor any of the Contractor's quality control testing and to perform duplicate testing as a check to the Contractor's quality control testing.

#### 3.10.3 Sampling

When directed by the Contracting Officer, sample and test any material which appears inconsistent with similar material being produced, unless such material is voluntarily removed and replaced or deficiencies corrected by the Contractor. All sampling shall be in accordance with standard procedures specified.

### 3.11 MATERIAL ACCEPTANCE

Testing for acceptability of work will be performed by an independent laboratory hired by the Contractor. Forward test results and payment calculations daily to the Contracting Officer. Acceptance of the plant produced mix and in-place requirements will be on a lot to lot basis. A standard lot for all requirements will be equal to 8 hours of production. Where appropriate, adjustment in payment for individual lots of hot-mix asphalt will be made based on in-place density, laboratory air voids, grade and smoothness in accordance with the following paragraphs. Grade and surface smoothness determinations will be made on the lot as a whole. Exceptions or adjustments to this will be made in situations where the mix within one lot is placed as part of both the intermediate and surface courses, thus grade and smoothness measurements for the entire lot cannot be made. In order to evaluate laboratory air voids and in-place (field) density, each lot will be divided into four equal sublots.

#### 3.11.1 Sublot Sampling

One random mixture sample for determining laboratory air voids, theoretical maximum density, and for any additional testing the Contracting Officer desires, will be taken from a loaded truck delivering mixture to each sublot, or other appropriate location for each sublot. All samples will be selected randomly, using commonly recognized methods of assuring randomness conforming to ASTM D3665 and employing tables of random numbers or computer programs. Laboratory air voids will be determined from three laboratory compacted specimens of each sublot sample in accordance with ASTM D6926. The specimens will be compacted within 2 hours of the time the mixture was loaded into trucks at the asphalt plant. Samples will not be reheated prior to compaction and insulated containers will be used as necessary to maintain the temperature.

#### 3.11.2 Additional Sampling and Testing

The Contracting Officer reserves the right to direct additional samples and tests for any area which appears to deviate from the specification requirements. The cost of any additional testing will be paid for by the Government. Testing in these areas will be in addition to the lot testing, and the requirements for these areas will be the same as those for a lot.

#### 3.11.3 Grade

The final wearing surface of pavement shall conform to the elevations and



cross sections shown and shall vary not more than 0.05 foot from the plan grade established and approved at site of work. Finished surfaces at juncture with other pavements shall coincide with finished surfaces of abutting pavements. Deviation from the plan elevation will not be permitted in areas of pavements where closer conformance with planned elevation is required for the proper functioning of drainage and other appurtenant structures involved. The grade will be determined by running lines of levels at intervals of 25 feet, or less, longitudinally and transversely, to determine the elevation of the completed pavement surface. Within 5 working days, after the completion of a particular lot incorporating the final wearing surface, test the final wearing surface of the pavement for conformance with the specified plan grade. Diamond grinding may be used to remove high spots to meet grade requirements. Skin patching for correcting low areas or planing or milling for correcting high areas will not be permitted.

#### 3.11.4 Surface Smoothness

Perform all testing in the presence of the Contracting Officer. Keep detailed notes of the results of the testing and furnish a copy to the Government immediately after each day's testing. Where drawings show required deviations from a plane surface (crowns, drainage inlets, etc.), the surface shall be finished to meet the approval of the Contracting Officer.

##### 3.11.4.1 Smoothness Requirements

###### 3.11.4.1.1 Straightedge Testing

The finished surfaces of the pavements shall have no abrupt change of 1/4 inch or more, and all pavements shall be within the tolerances of 1/4 inch in both the longitudinal and transverse directions, when tested with an approved 12 feet straightedge.

##### 3.11.4.2 Testing Method

After the final rolling, but not later than 24 hours after placement, test the surface of the pavement in each entire lot in such a manner as to reveal all surface irregularities exceeding the tolerances specified above. Separate testing of individual sublots is not required. If any pavement areas are ground, these areas shall be retested immediately after grinding. Test each lot of the pavement in both a longitudinal and a transverse direction on parallel lines. Set the transverse lines 15 feet or less apart, as directed. The longitudinal lines shall be at the centerline of each paving lane for lanes less than 20 feet wide and at the third points for lanes 20 feet or wider. Also test other areas having obvious deviations. Longitudinal testing lines shall be continuous across all joints.

###### 3.11.4.2.1 Straightedge Testing

Hold the straightedge in contact with the surface and move it 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 allowing it to rest upon the two highest spots covered by its length, and measuring the maximum gap between the straightedge and the pavement surface in the area between these two high points.

-- 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 (2023) 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	(2022) 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	(2022) 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	(2021) 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	(2023) 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
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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
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### 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

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  
Commercial Laboratory

#### 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				
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	<b><u>Finished Surface Measurements at Joint Intersections</u></b> (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 <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub> > 70 percent	25	35
SiO <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub> > 80 percent	20	35
SiO <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub> > 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 14 13.13

INTERLOCKING PRECAST CONCRETE UNIT PAVING  
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 C33/C33M	(2023) Standard Specification for Concrete Aggregates
ASTM C88	(2018) Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
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 C140/C140M	(2020a) Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
ASTM C144	(2018) Standard Specification for Aggregate for Masonry Mortar
ASTM C535	(2016) Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C936/C936M	(2020) Standard Specification for Solid Concrete Interlocking Paving Units
ASTM C979/C979M	(2016) Standard Specification for Pigments for Integrally Colored Concrete
ASTM C1645/C1645M	(2019) Standard Test Method for Freeze-thaw and De-icing Salt Durability of Solid Concrete Interlocking Paving Units
ASTM D75/D75M	(2019) Standard Practice for Sampling

Aggregates

ASTM D2488	(2017; E 2018) Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)
ASTM D4318	(2017; E 2018) Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D5821	(2013; R 2017) Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
ASTM D7428	(2015) Standard Test Method for Resistance of Fine Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus
ASTM E11	(2022) Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

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

SD-04 Samples

Field-Constructed Mock-Up; G

Concrete Paving Unit; G

SD-06 Test Reports

Tests, Inspections and Verifications

SD-07 Certificates

Paving Unit Installer Field Supervisor; G

Provide a copy of an ICPI Concrete Paver Installer School Certification, including a record of completion from a PICP or Permeable Interlocking Concrete Pavement Installer Technician Course.

1.3 DELIVERY, STORAGE AND HANDLING

Deliver materials in manufacturer's original, unopened, undamaged container packaging with identification tags intact on each paver bundle. Coordinate delivery and paving schedule to minimize interference with normal use of buildings adjacent to paving. Deliver concrete pavers to the site in steel banded, plastic banded, or plastic wrapped bundles capable of transfer by forklift or clamp lift. Unload pavers at job site in such a manner that no damage occurs to the product or to existing construction.

Stockpile jointing, bedding, base and subbase aggregates such that they do not segregate within each pile. Keep piles (1) free from standing water,

(2) free of organic material, sediment, or debris, and (3) ready for placement. Store aggregates on paved surfaces. Do not store aggregates on exposed soil or grassed areas unless first covered with geotextile to keep the aggregates clean.

#### 1.4 QUALITY ASSURANCE

##### 1.4.1 Concrete Paver Installer Certification

A paving unit installer field supervisor with a certificate of completion from the Interlocking Concrete Pavement Institute (ICPI) Concrete Paver Installer School Certification is required.

##### 1.4.2 Pre-Construction Meeting

Prior to starting work, hold a pre-construction meeting with the project engineer or other Government representative responsible for the project. Determine the following:

- a. Delivery and storage locations for aggregates and concrete paving unit bundles;
- b. Anticipated start date;
- c. Starting point(s) and direction(s) of paving;
- d. Methods for checking slopes and surface tolerances for smoothness and elevations;
- e. Estimated daily production for installation of aggregates, edge restraints and paving units; and
- f. Recording and reporting actual daily paving production, including identifying the site location and recording the number of bundles installed each day.

For machine assisted installation of paving units, review:

- a. Concrete unit manufacturer's written method that explains processes for controlling paver dimensional tolerances, and
- b. Diagram(s) of the concrete paver laying pattern and how the paver layers or clusters join together to provide a continuous pattern across the pavement surface.

##### 1.4.3 Weather Requirements

Do not install paver units during rain or snow events or when jointing sand, bedding sand, base or subbase aggregates are frozen. Do not place base or subbase aggregates on frozen soil subgrades.

##### 1.4.4 Field-Constructed Mock-Up

Install paver units on a minimum 10 x 10 ft area to determine surcharge of the bedding layer, joint sizes, and lines, laying pattern, color and texture of the job. Use this area as the standard by which the work is judged. Subject to acceptance by Contracting Officer or project engineer, allow the mock-up to be retained as part of finished work. If mock-up is not retained, remove mock-up from the installation boundary and properly

dispose of material.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Bedding and Jointing Sand

Use two separate sand gradations for the bedding layer and for the paver unit joints.

Prepare bedding sand and gradation in accordance with:

- a. ASTM C33/C33M with a maximum amount passing the No. 200 sieve of 1 percent.
- b. A maximum loss of 8 percent in accordance with ASTM D7428 and a maximum loss of 7 percent in accordance with ASTM C88.
- c. A minimum of 60 percent combined sub-angular and sub-rounded particle shapes in accordance with ASTM D2488

Prepare jointing sand gradation in accordance with:

- a. ASTM C144 with a maximum of 100 percent passing the No. 16 sieve and no more than 5 percent passing the No. 200 sieve.

Prepare bedding and jointing sand in accordance with:

- a. Material consisting of crushed sand, natural sand, or a combination of crushed and natural sand.
- b. A minimum L.A. Abrasion of 40 percent when tested in accordance with ASTM C131/C131M and ASTM C535.
- c. A minimum of 90 percent fractured faces in accordance with ASTM D5821.
- d. Nonplastic when tested in accordance with ASTM D4318 and free of lumps, clay, vegetation, soft particles, sulphates, and other contaminants.
- e. The following gradations, determined in accordance with ASTM C136/C136M and ASTM C117, using ASTM E11 sieve.

Sieve (ASTM E11)	Percent Passing	
	Bedding Sand	Jointing Sand
3/8 in	100	-
No. 4	95-100	100
No. 8	80-100	95-100
No. 16	50-85	70-100

Sieve (ASTM E11)	Percent Passing	
	Bedding Sand	Jointing Sand
No. 30	25-60	40-75
No. 50	5-30	10-35
No. 100	0-10	2-15
No. 200	0-1	0-5

### 2.1.2 Concrete Paving Unit

Submit a sample of five paving units prior to the start of the work. Also, a representative sample of not less than 15 units as directed by the Contracting Officer, from each lot of 20,000 concrete paving units or fraction thereof. Use concrete paving units that are in accordance with ASTM C936/C936M and 3 1/8 thick and rectangular in shape. Use units with a pigmentation in accordance with ASTM C979/C979M.

## 2.2 TESTS, INSPECTIONS AND VERIFICATIONS

Submit a written report within seven (7) calendar days after completion of the work, covering the following testing which is required for each lot.

### 2.2.1 Paving Unit

Conduct the tests prescribed by ASTM C936/C936M and the following tests on the remaining units of each sample from each lot.

Submit samples of the paving units to be utilized for the purpose of verifying the color and shape 30 days prior to the start of work.

#### 2.2.1.1 Freezing and Thawing

Determine the resistance to freezing and thawing in accordance with ASTM C1645/C1645M and check that the results meet the freeze-thaw requirements stated in ASTM C936/C936M.

#### 2.2.1.2 Dimensional Tolerance

Sample and measure three paving units from each lot in accordance with ASTM C140/C140M. Do not permit the length and width of each unit in the sample to vary from other units in this or other lot samples by more than 1/16 in. Do not permit the thickness of the unit in the sample to vary by more than 1/8 in from the specified unit thickness.

#### 2.2.1.3 Compressive Strength

Test three paving units in accordance with ASTM C140/C140M. Do not permit the average minimum compressive strength to be less than 8,000 psi with no individual unit less than 7,200 psi.

#### 2.2.1.4 Retest

Notify the Contracting Officer if units fail to meet the specified

requirements. In case the shipment fails the specified requirements, take another sample and new specimens selected from the retained lot for retesting, as directed by the Contracting Officer. Concrete paving unit retests are to be performed at the expense of the Contractor. In case the second set of specimens fails to meet the test requirements, reject the entire lot.

### 2.2.2 Bedding and Jointing Sand

Obtain representative samples of bedding and jointing sand in accordance with ASTM D75/D75M from each 100 cubic yds of sand to be used in the project. If the sand fails to meet the gradation requirements take another sample and retest it at no cost to the Government. If this retest fails or if no second test is taken, reject the sand and remove from the job site.

## PART 3 EXECUTION

### 3.1 PREPARATION

#### 3.1.1 Bedding Sand Layer

Spread the bedding sand evenly over the area to be paved and screed to an uncompacted average thickness of 1 in with a tolerance for grade and surface smoothness of plus or minus 1/4 in. Do not use this bedding sand to fill low areas that exceed the specified tolerance for the base. Leave the sand uncompacted and do not disturb by pedestrian or vehicle construction traffic.

### 3.2 UNIT PLACEMENT

Place the paving units by hand or machine in a herringbone pattern. Start the placement of paving units from a corner or straight edge and proceed forward over the undisturbed sand bedding layer. Do not permit the joints, excluding chamfer between paving units, to be less than 1/16 in or more than 3/16 in in width. After seating, check that the unit surface is flush or up to 1/4 in above the edge restraint.

#### 3.2.1 Unfilled Gaps

Fill gaps between paving units and the edge restraint, drainage structure, or other member that cannot be filled with a whole unit with a paving unit cut to fit the gap, except do not allow slivers and the minimum size of cut unit is 1/3 the original unit size. Use a hydraulic splitter, a masonry saw, or other device that accurately leaves a clean, vertical face without spalling for cutting. Do not accept a remaining gap between the unit and adjoining edge restraint, drainage structures, or other member that is greater than 1/4 in. Cut or rearrange adjacent units to prevent this.

#### 3.2.2 Seating Units

Seat the units in the bedding sand by compacting them with a minimum of three passes of a vibratory plate compactor, minimum 5,000 lbf.

#### 3.2.3 Jointing Sand

Sweep the jointing sand into joints and vibrate with a vibratory plate or vibratory roller compactor. Continue this process until sweeping and

vibrating have filled joints with sand and further vibration cannot force additional sand into the joints. Sweep the coarser sand particles that did not enter the joints and remain on the surface and excess sand on the surface off the pavement.

#### 3.2.4 Timing of Operations

Seating of units and placement of jointing sand can be done concurrently with unit placement. However, do not allow seating of units and placement of jointing sand within 5 ft of an unfinished edge of the pavement that is not supported by the edge restraint.

#### 3.2.5 Final Rolling

Roll the final finished paving unit surface with four passes of a vibratory or pneumatic roller with a static weight of not less than 10,000 lbs.

#### 3.2.6 Construction Traffic

Do not allow construction traffic on the paving unit surface until the jointing sand has been placed and vibrated into the joints and debris and excess sand have been swept off.

### 3.3 SMOOTHNESS AND GRADE TOLERANCES

#### 3.3.1 Smoothness

Do not allow a portion of the finished pavement surface to deviate by more than 3/8 in from a 10 ft long metal straightedge placed on the pavement surface.

#### 3.3.2 Unit Height

Check that the finished unit surface is either flush or up to 1/4 in higher than edge restraints or drainage structures.

#### 3.3.3 Grade

Check that the finished pavement is within 1/2 in of the planned grade shown on the plans.

#### 3.3.4 Remedial Action

Remove paver units and sand in those area not meeting the smoothness, unit height, or grade tolerance, adjust aggregate base grade, and relay the units and sand.

### 3.4 CLEANUP

Sweep the entire pavement surface and remove excess sand, units and debris from the project area.

-- End of Section --





SECTION 32 15 00

AGGREGATE SURFACING  
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.

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
- AASHTO T 224 (2010) Standard Method of Test for Correction for Coarse Particles in the Soil Compaction Test

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<sup>3</sup>) (2700 kN-m/m<sup>3</sup>)
- ASTM D2167 (2015) Density and Unit Weight of Soil in Place by the Rubber Balloon Method
- ASTM D4318 (2017; E 2018) Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity 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 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 abbreviated as a percent of laboratory maximum dry 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, the degree of compaction for material having more than 30 percent by weight of their particles retained on the 3/4 inch sieve will be expressed as a percentage of the laboratory maximum dry density in accordance with AASHTO T 180 Method D and corrected with AASHTO T 224.

## 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-03 Product Data

Plant, Equipment, and Tools; G

SD-06 Test Reports

Initial Tests; G

In-Place Tests; G

## 1.4 EQUIPMENT, TOOLS, AND MACHINES

All plant, equipment, and tools used in the performance of the work will be subject to approval by the Contracting Officer 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. Provide adequate equipment having the capability of minimizing segregation, producing the required compaction, meeting grade controls, thickness control, and smoothness requirements as set forth herein.

## 1.5 QUALITY ASSURANCE

Sampling and testing are the responsibility of the Contractor. Perform sampling and testing using a laboratory approved in accordance with Section 01 45 00 QUALITY CONTROL. Work requiring testing will not be permitted until the testing laboratory has been inspected and approved. Test the materials to establish compliance with the specified requirements and perform testing at the specified frequency. The Contracting Officer may specify the time and location of the tests. Furnish copies of test

results to the Contracting Officer within 24 hours of completion of the tests.

#### 1.5.1 Sampling

Take samples for laboratory testing in conformance with ASTM D75/D75M. When deemed necessary, the sampling will be observed by the Contracting Officer.

#### 1.5.2 Testing

##### 1.5.2.1 Sieve Analysis

Perform sieve analysis in conformance with ASTM C117 and ASTM C136/C136M using sieves conforming to ASTM E11.

##### 1.5.2.2 Liquid Limit and Plasticity Index

Determine liquid limit and plasticity index in accordance with ASTM D4318.

##### 1.5.2.3 Moisture-Density Determinations

Determine the laboratory maximum dry density and optimum moisture content in accordance with paragraph DEGREE OF COMPACTION.

##### 1.5.2.4 Field Density Tests

Measure field density in accordance with ASTM D1556/D1556M, ASTM D2167 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 paragraph Calibration, of the ASTM publication. Tests performed in accordance with ASTM D6938 result in a wet unit weight of soil and ASTM D6938 will be used to determine the moisture content of the soil. Also 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 paragraph Calibration of ASTM D6938, on each different type of material being 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.

##### 1.5.2.5 Wear Test

Perform wear tests on aggregate surface course material in conformance with ASTM C131/C131M.

## PART 2 PRODUCTS

### 2.1 AGGREGATES

Provide aggregates consisting of clean, sound, durable particles of natural gravel, crushed gravel, crushed stone, sand, slag, soil, or other approved materials processed and blended or naturally combined. Provide aggregates free from lumps and balls of clay, organic matter, objectionable coatings, and other foreign materials. The Contractor is responsible for obtaining materials that meet the specification and can be used to meet the grade and smoothness requirements specified herein after

all compaction operations have been completed.

2.1.1 Coarse Aggregates

The material retained on the No. 4 sieve is known as coarse aggregate. Use only coarse aggregates that are reasonably uniform in density and quality. Use only coarse aggregate having a percentage of wear not exceeding 50 percent after 500 revolutions as determined by ASTM C131/C131M. The amount of flat and/or elongated particles must not exceed 20 percent. A flat particle is one having a ratio of width to thickness greater than three; an elongated particle is one having a ratio of length to width greater than three. When the coarse aggregate is supplied from more than one source, aggregate from each source must meet the requirements set forth herein.

2.1.2 Fine Aggregates

The material passing the No. 4 sieve is known as fine aggregate. Fine aggregate consists of screenings, sand, soil, or other finely divided mineral matter that is processed or naturally combined with the coarse aggregate.

2.1.3 Gradation Requirements

Gradation requirements specified in TABLE I apply to the completed aggregate surface. It is the responsibility of the Contractor to obtain materials that will meet the gradation requirements after mixing, placing, compacting, and other operations. TABLE I shows permissible gradings for granular material used in aggregate surface roads and airfields. Use sieves conforming to ASTM E11.

TABLE I. GRADATION FOR AGGREGATE SURFACE COURSES Percentage by Weight Passing Square-Mesh Sieve				
Sieve Designation	No. 1	No. 2	No. 3	No. 4
1 inch	100	100	100	100
3/8 inch	50-85	60-100	--	--
No. 4	35-65	50-85	55-100	70-100
No. 10	25-50	40-70	40-100	55-100
No. 40	15-30	24-45	20-50	30-70
No. 200	8-15	8-15	8-15	8-15

2.2 LIQUID LIMIT AND PLASTICITY INDEX

The portion of the completed aggregate surface course passing the No. 40 sieve must have a maximum liquid limit of 35 and a plasticity index of 4 to 9.

## 2.3 TESTS, INSPECTIONS, AND VERIFICATIONS

### 2.3.1 Initial Tests

Perform one of each of the following tests, on the proposed material prior to commencing construction, to demonstrate that the proposed material meets all specified requirements when furnished. Complete this testing for each source if materials from more than one source are proposed.

- a. Sieve Analysis.
- 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.

### 2.3.2 Approval of Material

Tentative approval of material will be based on initial test results.

## PART 3 EXECUTION

### 3.1 OPERATION OF AGGREGATE SOURCES

Finalize aggregate sources on private lands in agreement with local laws or authorities.

### 3.2 STOCKPILING MATERIAL

Prior to stockpiling the material, clear and level the storage sites. Stockpile all materials, including approved material available from excavation and grading, in the manner and at the locations designated. Stockpile aggregates in such a manner that will prevent segregation. Stockpile aggregates and binders obtained from different sources separately.

### 3.3 PREPARATION OF UNDERLYING SUBGRADE

Clean the subgrade and shoulders of all foreign substances. Do not construct the surface course on subgrade that is frozen material. Correct ruts or soft yielding spots in the subgrade, areas having inadequate compaction and deviations of the surface from the requirements set forth herein by loosening and removing soft or unsatisfactory material and by adding approved material, reshaping to line and grade and recompacting to density requirements specified in Section 31 00 00 EARTHWORK. Do not allow traffic or other operations to disturb the completed subgrade and maintain in a satisfactory condition until the surface course is placed.

### 3.4 GRADE CONTROL

During construction, maintain the lines and grades including crown and cross slope indicated for the aggregate surface course by means of line and grade stakes placed by the Contractor in accordance with the SPECIAL CONTRACT REQUIREMENTS.

### 3.5 MIXING AND PLACING MATERIALS

Mix and place the materials to obtain uniformity of the material and a uniform optimum water content for compaction. Make adjustments in mixing, placing procedures, or in equipment to obtain the true grades, to minimize segregation and degradation, to obtain the desired water content, and to ensure a satisfactory surface course.

### 3.6 LAYER THICKNESS

Place the aggregate material on the subgrade in layers of uniform thickness. Compact the completed aggregate surface course to the thickness indicated. No individual layer may be thicker than 6 inches nor be thinner than 3 inches in compacted thickness. Compact the aggregate surface course to a total thickness that is within 1/4 inch of the thickness indicated. 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 1/4 inch thicker than indicated, the course will be considered as conforming to the specified thickness requirements. The average job thickness will be the average of all thickness measurements taken for the job and must be within 1/4 inch of the thickness indicated. Measure the total thickness of the aggregate surface course at intervals of one measurement for each 100 square yards of surface course. Measure total thickness using 3 inch diameter test holes penetrating the aggregate surface course.

### 3.7 COMPACTION

Degree of compaction is a percentage of the maximum density obtained by the test procedure presented in ASTM D1557 abbreviated herein as percent laboratory maximum density. Compact each layer of the aggregate surface course with approved compaction equipment, as required in the following paragraphs. Maintain the water content during the compaction procedure at optimum or at the percentage specified by the Contracting Officer. Compact the mixture with mechanical tampers in locations not accessible to rollers. Continue compaction until each layer through the full depth is compacted to at least 100 percent of laboratory maximum density. Remove any materials that are found to be unsatisfactory and replace them with satisfactory material or rework them to produce a satisfactory material.

### 3.8 EDGES OF AGGREGATE SURFACE COURSE

Place approved material along the edges of the aggregate surface course in such quantity as to compact to the thickness of the course being constructed. Simultaneously roll and compact at least 1 foot of shoulder width with the rolling and compacting of each layer of the surface course when the course is being constructed in two or more layers.

### 3.9 SMOOTHNESS TEST

Construct each layer so that the surface shows no deviations in excess of 3/8 inch when tested with a 10 foot straightedge applied both parallel with and at right angles to the centerline of the area to be paved. Correct deviations exceeding this amount by removing material, replacing with new material, or reworking existing material and compacting, as directed.

### 3.10 FIELD QUALITY CONTROL

#### 3.10.1 In-Place Tests

Perform each of the following tests on samples taken from the placed and compacted aggregate surface course. 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 100 square yards, or portion thereof, of completed area.
- b. Perform sieve analysis on every lift of material placed and at a frequency of one sieve analysis for every 500 square yards, or portion thereof, of material placed.
- c. Perform liquid limit and plasticity index tests at the same frequency as the sieve analysis.
- d. Measure the thickness of the aggregate surface course at intervals providing at least one measurement for each 100 square yards of base course or part thereof. Measure the thickness using test holes, at least 3 inch in diameter through the aggregate surface course.

#### 3.10.2 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 full compacted aggregate surface course.

### 3.11 MAINTENANCE

Maintain the aggregate surface course in a condition that will meet all specification requirements until accepted.

-- 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 (2023) 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 (2016) Standard Specification for Sheet Materials for Curing Concrete

ASTM C172/C172M (2017) Standard Practice for Sampling Freshly Mixed Concrete

ASTM C173/C173M (2016) Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

ASTM C231/C231M (2022) Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

ASTM C309 (2011) 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 5 to 7 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 1/2 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.

### 2.6.4 Curb and Gutter Forms

Use curb and gutter outside forms that have a height equal to the full depth of the curb or gutter. Use rigid forms for curb returns, except that benders or thin plank forms may be used for curb or curb returns with a radius of 10 feet or more, where grade changes occur in the return, or where the central angle is such that a rigid form with a central angle of 90 degrees cannot be used. Back forms for curb returns may be made of 1-1/2 inch benders, for the full height of the curb, cleated together. In lieu of inside forms for curbs, a curb "mule" may be used for forming and finishing this surface, provided the results are approved.

## 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 SIDEWALK AND SUBBASE FOR FLEXIBLE PAVING. 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 Curb and Gutter Subgrade

Place and compact the subgrade in accordance with Section 31 00 00 EARTHWORK and Section 32 11 20 Base Course for Rigid and Subbase for Flexible Paving. Test the subgrade for grade and cross section by means of a template extending the full width of the curb and gutter. Use subgrade materials equal in bearing quality to the subgrade under the adjacent pavement.

#### 3.1.3 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.

### 3.2.2 Curbs and Gutters

Remove forms used along the front of the curb not less than 2 hours nor more than 6 hours after the concrete has been placed. Do not remove forms used along the back of curb until the face and top of the curb have been finished, as specified for concrete finishing. Do not remove gutter forms while the concrete is sufficiently plastic to slump in any direction.

## 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 CURB AND GUTTER CONCRETE PLACEMENT AND FINISHING

### 3.4.1 Formed Curb and Gutter

Place concrete to the required section in a single lift. Consolidate concrete using approved mechanical vibrators. Curve shaped gutters must be finished with a standard curb "mule".

### 3.4.2 Curb and Gutter Finishing

Approved slipformed curb and gutter machines may be used in lieu of hand placement.

### 3.4.3 Concrete Finishing

Float and finish exposed surfaces with a smooth wood float until true to grade and section and uniform in texture. Brush floated surfaces with a fine-hair brush using longitudinal strokes. Round the edges of the gutter and top of the curb with an edging tool to a radius of 2-inch. Immediately after removing the front curb form, rub the face of the curb with a wood or concrete rubbing block and water until blemishes, form marks, and tool marks have been removed. Brush the front curb surface, while still wet, in the same manner as the gutter and curb top. Finish the top surface of gutter and entrance to grade with a wood float.

### 3.4.4 Joint Finishing

Finish curb edges at formed joints as indicated.

### 3.4.5 Surface and Thickness Tolerances

Finished surfaces must not vary more than 1/4 inch from the testing edge of a 10-foot straightedge. Permissible deficiency in section thickness will be up to 1/4 inch.

## 3.5 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 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.

### 3.5.1 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.

### 3.5.2 Sidewalk Expansion Joints

Form expansion joints using 1/2-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.

### 3.5.3 Reinforcement Steel Placement

Accurately and securely fasten reinforcement steel in place with suitable supports and ties before the concrete is placed.

## 3.6 CURB AND GUTTER JOINTS

Construct curb and gutter joints at right angles to the line of curb and gutter.

### 3.6.1 Contraction Joints

Construct contraction joints directly opposite contraction joints in abutting portland cement concrete pavements and spaced so that monolithic sections between curb returns will not be less than 5 feet nor greater than 15 feet in length.

- a. Construct contraction joints (except for slip forming) by means of 1/8-inch thick separators and of a section conforming to the cross section of the curb and gutter. Remove separators as soon as practicable after concrete has set sufficiently to preserve the width and shape of the joint and prior to finishing.
- b. When slip forming is used, cut the contraction joints in the top portion of the gutter/curb hardened concrete in a continuous cut across the curb and gutter, using a power-driven saw. Cut the contraction joint to a depth of at least one-fourth of the gutter/curb depth using a 1/8 inch saw blade.

### 3.6.2 Expansion Joints

Form expansion joints by means of preformed expansion joint filler material cut and shaped to the cross section of curb and gutter.

Construct expansion joints in curb and gutter directly opposite expansion joints of abutting portland cement concrete pavement using the same type and thickness of joints as joints in the pavement. Where curb and gutter do not abut portland cement concrete pavement, provide expansion joints at least 1/2 inch in width at intervals not less than 30 feet nor greater than 120 feet. Seal expansion joints immediately following curing of the concrete or as soon thereafter as weather conditions permit. Seal expansion joints and the top 1 inch depth of curb and gutter contraction-joints with joint sealant. Thoroughly clean the joint opening before the sealing material is placed. Do not spill sealing material on exposed surfaces of the concrete. Concrete at the joint must be surface dry and atmospheric and concrete temperatures must be above 50 degrees F at the time of application of joint sealing material. Immediately remove excess material on exposed surfaces of the concrete and clean concrete surfaces.

### 3.7 CURING AND PROTECTION

#### 3.7.1 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.

##### 3.7.1.1 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.

##### 3.7.1.2 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.

##### 3.7.1.3 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.

### 3.7.2 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.

### 3.7.3 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.

## 3.8 FIELD QUALITY CONTROL

Submit copies of all test reports within 24 hours of completion of the test.

### 3.8.1 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.

### 3.8.2 Concrete Testing

#### 3.8.2.1 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.

#### 3.8.2.2 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.

#### 3.8.2.3 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.

#### 3.8.3 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.

#### 3.8.4 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.

### 3.9 SURFACE DEFICIENCIES AND CORRECTIONS

#### 3.9.1 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.

#### 3.9.2 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.

### 3.9.3 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

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 D6628 (2003; R 2015) Standard Specification for Color of Pavement Marking Materials

U.S. FEDERAL HIGHWAY ADMINISTRATION (FHWA)

MUTCD (2009; Rev 2012) Manual on Uniform Traffic Control Devices

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

Surface Preparation Equipment List; G

Application Equipment List; G

Exterior Surface Preparation

Safety Data Sheets; G

Waterborne Paint; G

SD-06 Test Reports

Waterborne Paint; G

SD-07 Certificates

Qualifications; G

Waterborne Paint

Volatile Organic Compound, (VOC); G

SD-08 Manufacturer's Instructions

Waterborne Paint; G

### 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.

### 1.4 DELIVERY AND STORAGE

Deliver paint 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 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.

#### 1.5.2 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 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. 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 Equipment for Roads and Automotive Parking Areas

Submit a surface preparation equipment list by serial number, type, model, and manufacturer. Include descriptive data indicating area of coverage per pass, pressure adjustment range, tank and flow capacities, and safety precautions required for the equipment operation. Mobile equipment must allow for removal of markings without damaging the pavement surface or joint sealant. Maintain machines, tools, and equipment used in the performance of the work in satisfactory operating condition.

##### 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.

## 2.2 MATERIALS

Use non-reflectORIZED waterborne paint for automotive parking areas. 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. Provide materials conforming to the requirements specified herein.

### 2.2.1 Waterborne Paint

## 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. 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 18 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 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 and other coatings adhering to the pavement by water blasting.

### 3.2.1 Early Painting of Asphalt Pavements

For asphalt pavement systems requiring painting application at less than 30 days, apply the paint 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 Roads

Apply paint at a rate of 105 plus or minus 5 square feet per gallon.

### 3.3.2 Cleanup and Waste Disposal

Keep the worksite clean and free of debris and waste from the application operations. Dispose of debris at approved sites.

### 3.4 FIELD QUALITY CONTROL

#### 3.4.1 Sampling and Testing

As soon as the paint materials 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.

-- End of Section --

SECTION 32 31 13

CHAIN LINK FENCES AND GATES

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 A491	(2011; R 2017) Standard Specification for Aluminum-Coated Steel Chain-Link Fence Fabric
ASTM A824	(2001; R 2017) Standard Specification for Metallic-Coated Steel Marcellled Tension Wire for Use With Chain Link Fence
ASTM C94/C94M	(2023) Standard Specification for Ready-Mixed Concrete
ASTM F567	(2014a; R 2019) Standard Practice for Installation of Chain Link Fence
ASTM F626	(2014; R 2019) Standard Specification for Fence Fittings

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS RR-F-191/1	(Rev F) Fencing, Wire and Post, Metal (Chain-Link Fence Fabric)
FS RR-F-191/3	(Rev E; Am 1) Fencing, Wire and Post, Metal (Chain-Link Fence Posts, Top Rails and Braces)
FS RR-F-191/4	(Rev F) Fencing, Wire and Post, Metal (Chain-Link Fence Accessories)

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-02 Shop Drawings

Fence Assembly; G

Location of Gate, Corner, End, and Pull Posts; G

Erection/Installation Drawings; G

SD-03 Product Data

Fence Assembly; G

Aluminum Alloy Coating; G

Fabric; G

Stretcher Bars; G

Concrete; G

SD-04 Samples

Fabric; G

Posts; G

Braces; G

Line Posts; G

Sleeves; G

Tension Wire; G

Stretcher Bars; G

Wire Ties; G

SD-07 Certificates

Certificates of Compliance

SD-08 Manufacturer's Instructions

Fence Assembly

SD-11 Closeout Submittals

Recycled Material Content; S

### 1.3 QUALITY CONTROL

#### 1.3.1 Certificates of Compliance

Submit certificates of compliance in accordance with the applicable reference standards and descriptions of this section for the following:

- a. Zinc coating
- b. Aluminum alloy coating

- c. Fabric
- d. Stretcher bars
- e. Concrete

#### 1.4 DELIVERY, STORAGE, AND HANDLING

Deliver materials to site in an undamaged condition. Store materials off the ground to provide protection against oxidation caused by ground contact.

### PART 2 PRODUCTS

#### 2.1 SYSTEM DESCRIPTION

Submit reports of listing chain-link fencing and accessories regarding weight in ounces for zinc coating and chemical composition and thickness of aluminum alloy coating.

Submit manufacturer's catalog data for complete fence assembly.

#### 2.2 FENCES

##### 2.2.1 Fabric

FS RR-F-191/1; Type II, aluminum-coated steel, 9 gauge, conforming to ASTM A491. Height of fabric, as indicated.

Provide fabric consisting of wires woven into a 2-inch diamond mesh. Provide one-piece fabric widths for fence heights up to 12 feet.

##### 2.2.1.1 Top and Bottom Selvages

Provide twisted and barbed top selvage and knuckled bottom selvages.

##### 2.2.2 Posts

##### 2.2.2.1 Metal

##### 2.2.2.1.1 Line Posts

Provide line posts complying with FS RR-F-191/3. Provide Class 1, steel pipe, Grade A Regular Strength, with a nominal diameter of 2 inches.

##### 2.2.2.1.2 End, Corner and Pull Posts

Provide end, corner, and pull posts with a nominal diameter of 2 inches. Provide Class 1, steel pipe, Grade A Regular Strength.

##### 2.2.2.2 Post Tops

Provide steel tops designed as a weathertight closure cap. Post top to have finish and coating matching rails and posts. Steel type to be pressed steel galvanized after fabrication having a minimum zinc coating of 1.2 ounces per square foot. Provide one cap for each post, unless equal protection is provided by a combination post-cap and wire supporting arm.

### 2.2.3 Braces

Class 1, steel pipe, Grade A Regular Strength with an outside diameter of 1.660 inches.

#### 2.2.3.1 Post-Brace Assembly

Provide bracing conforming to minimum sizes specified in FS RR-F-191/3 for each class and grade, and 3/8 inch adjustable truss rods and turnbuckles.

### 2.2.4 Wire Ties

Provide 9-gauge wire for tying fabric to line posts, spaced 12 inches on center. For tying fabric to rails and braces, space wire ties 24 inches on center. For tying fabric to tension wire, space 0.105-inch hog rings 24 inches on center. Manufacturer's standard procedure will be accepted if of equal strength and durability.

FS RR-F-191/4. Provide wire ties constructed of the same material and coating as the fencing fabric.

### 2.2.5 Sleeves

Provide sleeves for setting into concrete construction of the same material as post sections, sized 1 inch greater than the diameter or dimension of the post. Weld flat plates to each sleeve base to provide anchorage and prevent intrusion of concrete.

### 2.2.6 Stretcher Bars

Provide bars that have one-piece lengths equal to the full height of the fabric with a minimum cross section of 3/16 by 3/4 inch, in accordance with ASTM F626.

### 2.2.7 Stretcher Bar Bands

Provide bar bands for securing stretcher bars to posts that are steel, wrought iron, or malleable iron spaced not over 15 inches on center. Bands may also be used in conjunction with special fittings for securing rails to posts. Provide bands with projecting edges chamfered or eased.

### 2.2.8 Tension Wire

Provide metallic coated steel marcelled tension wire, (No. 7-gauge) complying with ASTM A824.

### 2.2.9 Miscellaneous Hardware

Provide miscellaneous hot-dip galvanized hardware as required.

## 2.3 MATERIALS

### 2.3.1 Concrete

Provide concrete conforming to ASTM C94/C94M, and obtaining a minimum 28-day compressive strength of 3,000 psi.

### 2.3.2 Grout

Provide grout of proportions one part Portland cement to three parts clean, well-graded sand and a minimum amount of water to produce a workable mix.

## PART 3 EXECUTION

Submit manufacturer's erection/installation drawings and instructions that detail proper assembly and materials in the design for fence, gate, hardware and accessories.

Provide complete installation conforming to ASTM F567.

### 3.1 PREPARATION

Ensure final grading and established elevations are complete prior to commencing fence installation.

#### 3.1.1 Clearing and Grading

Clear fence line of trees, brush, and other obstacles to install fencing for a distance of 10 feet inside; and 10 feet outside the fence. Establish a graded, compacted fence line prior to fencing installation.

### 3.2 INSTALLATION

#### 3.2.1 Security

Install new chain link fencing, remove existing fencing, and perform related work to provide continuous security for facility. Schedule and fully coordinate work with Contracting Officer and cognizant Security Officer.

#### 3.2.2 Fence Installation

Install fence on prepared surfaces to line and grade indicated. Install fence in accordance with fence manufacturer's written installation instructions except as modified herein.

##### 3.2.2.1 Post Spacing

Provide line posts spaced equidistantly apart, not exceeding 10 feet on center. Do not exceed 152.4 m (500 feet) on straight runs between braced posts. Provide corner or pull posts, with bracing in both directions, for changes in direction of 15 degrees or more, or for abrupt changes in grade. Submit drawings showing location of gate, corner, end, and pull posts.

##### 3.2.2.2 Top and Bottom Tension Wire

Install top and bottom tension wires before installing chain-link fabric, and pull wires taut. Place bottom tension wires within 8 inches of respective fabric line.

#### 3.2.3 Excavation

Provide excavations for post footings which are drilled holes in virgin or compacted soil, of minimum sizes as indicated. Space footings for line



posts 10 feet on center maximum and at closer intervals when indicated, with bottoms of the holes approximately 12 inches below the bottoms of the posts. Set bottom of each post not less than 36 inches below finished grade when in firm, undisturbed soil. Set posts deeper, as required, in soft and problem soils and for heavy, lateral loads. Uniformly spread soil from excavations adjacent to the fence line or on areas of Government property, as directed.

When solid rock is encountered near the surface, drill into the rock at least 12 inches for line posts and at least 18 inches for end, pull, corner, and gate posts. Drill holes at least 1 inch greater in diameter than the largest dimension of the placed post. If solid rock is below the soil overburden, drill to the full depth required except that penetration into rock need not exceed the minimum depths specified above.

#### 3.2.4 Setting Posts

Remove loose and foreign materials from holes and moisten the soil prior to placing concrete. Provide tops of footings that are trowel finished and sloped or domed to shed water away from posts. Set hold-open devices, sleeves, and other accessories in concrete.

Keep exposed concrete moist for at least 7 calendar days after placement or cured with a membrane curing material, as approved. Maintain vertical alignment of posts in concrete construction until concrete has set.

##### 3.2.4.1 Earth and Bedrock

Provide concrete bases of dimensions indicated on the manufacturer's installation drawings. Compact concrete to eliminate voids, and finish to a dome shape. In bedrock, set posts with a minimum of 1 inch of grout around each post. Work grout into hole to eliminate voids, and finish to a dome shape.

##### 3.2.4.2 Bracing

Brace gate, corner, end, and pull posts to nearest post with a horizontal brace used as a compression member, placed at least 12 inches below top of fence, and a diagonal tension rod.

##### 3.2.4.3 Tolerances

Provide posts that are straight and plumb within a vertical tolerance of 1/4 inch after the fabric has been stretched. Provide fencing and gates that are true to line with no more than 1/2 inch deviation from the established centerline between line posts. Repair defects as directed.

##### 3.2.5 Concrete Strength

Provide concrete that has attained at least 75 percent of its minimum 28-day compressive strength, but in no case sooner than 7 calendar days after placement, before rails, tension wire, or fabric are installed. Do not stretch fabric and wires or hang gates until the concrete has attained its full design strength.

##### 3.2.6 Brace Assembly

Provide bracing assemblies at end and gate posts and at both sides of corner and pull posts, with the horizontal brace located at midheight of

the fabric.

Install brace assemblies so posts are plumb when the diagonal rod is under proper tension. Provide two complete brace assemblies at corner and pull posts where required for stiffness and as indicated.

### 3.2.7 Tension Wire Installation

Install tension wire by weaving them through the fabric and tying them to each post with not less than 7-gauge galvanized wire or by securing the wire to the fabric with 10-gauge ties or clips spaced 24 inches on center.

### 3.2.8 Fabric Installation

Provide fabric in single lengths between stretch bars with bottom barbs placed approximately 1-1/2 inches above the ground line. Pull fabric taut and tied to posts, rails, and tension wire with wire ties and bands.

Install fabric on the security side of fence, unless otherwise directed. Ensure fabric remains under tension after the pulling force is released.

### 3.2.9 Stretcher Bar Installation

Thread stretcher bars through or clamped to fabric 4 inches on center and secured to posts with metal bands spaced 15 inches on center.

### 3.2.10 Tie Wires

Provide tie wires that are U-shaped to the pipe diameters to which attached. Twist ends of tie wires not less than two full turns and bent so as not to present a hazard.

### 3.2.11 Fasteners

Install nuts for tension bands and hardware on the side of the fence opposite the fabric side. Peen ends of bolts to prevent removal of nuts.

### 3.2.12 Accessories Installation

#### 3.2.12.1 Post Caps

Install post caps as recommended by the manufacturer.

### 3.2.13 Grounding

Ground fencing as specified.

Ground all fences crossed by overhead power lines in excess of 600 volts, and all electrical equipment attached to the fence. Ground fences on each side of all gates, at each corner, at the closest approach to each building located within 50 feet of the fence, and where the fence alignment changes more than 15 degrees. Grounding locations cannot exceed 650 feet. Bond each gate panel with a flexible bond strap to its gate post. Ground fences crossed by power lines of 600 volts or more at or near the point of crossing and at distances not exceeding 150 feet on each side of crossing. Provide ground conductor consisting of No. 6 AWG solid copper wire. Provide copper-clad steel rod grounding electrodes 3/4 inch by 10 foot long. Drive electrodes into the earth so that the top of the electrode is at least 6 inches below the grade. Where driving is

impracticable, bury electrodes a minimum of 12 inches deep and radially from the fence, with top of the electrode not less than 2 feet or more than 8 feet from the fence. Clamp ground conductor to the fence and electrodes with bronze grounding clamps to create electrical continuity between fence posts, fence fabric, and ground rods. Total resistance of the fence to ground cannot exceed 25 ohms.

### 3.3 CLOSEOUT ACTIVITIES

Remove waste fencing materials and other debris from the work site.

Submit manufacturer's data indicating percentage of recycled material content in protective fence materials, including chain link fence, fabric, and gates to verify affirmative procurement compliance.

-- 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 (2022) 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
ASTM D2564	(2020) Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems
ASTM D3034	(2016) Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings
ASTM F477	(2014; R 2021) Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

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

#### 2.1.2 Poly Vinyl Chloride (PVC) Pipe

##### 2.1.2.1 Type PSM PVC Pipe

ASTM D3034, maximum SDR 35.

### 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.

#### 2.2.2 PVC Plastic Pipe

Provide solvent cement or elastomeric gasket type joints in accordance with the specification for the pipe and as recommended by the pipe manufacturer. Use solvent cement conforming to ASTM D2564. Provide gaskets for elastomeric joints conforming to ASTM F477.

## 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 Modular Trench Drains

Provide modular trench drains consisting of plastic or precast concrete sections. Provide trench with width and invert slope as indicated on the drawings. Provide trench drain sections and grates rated for DIN Class D.

##### 2.3.8.1 Plastic Sections

Provide polyethylene, polypropylene, polyester, PVC or HDPE sections with UV inhibitors and interlocking tongue and groove joints. Provide channels with ductile iron frames.

##### 2.3.8.2 Precast Concrete Sections

Provide concrete sections made of fiber reinforced concrete or polyester polymer concrete with male/female connections between channel sections. Provide channels with ductile iron edge rails.

##### 2.3.8.3 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 overexcavation.

##### 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.

### 3.2.2 Plastic Pipe

Provide bedding for PVC, PE, SRPE and PP pipe meeting the requirements of ASTM D2321. Use Class IB or II material for PVC, PE, SRPE pipe bedding, haunching, and initial backfill. Use Class I, II, or III material for PP pipe bedding, haunching and initial backfill.

### 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. Deflection of installed flexible pipe must not exceed the following limits:

TYPE OF PIPE	MAXIMUM ALLOWABLE DEFLECTION (percent)
Corrugated Steel and Aluminum	5
Plastic (PVC, HDPE, SRPE, and PP)	5

#### 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 Flexible Pipe

Check each flexible pipe (PE, PVC, PP, corrugated steel and aluminum) for rips, tears, joint separations, soil migration through the joint, cracks, localized buckling, bulges, settlement and alignment.

##### 3.8.2.1.3 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.

##### 3.8.3.1.2 Flexible Pipe

Replace pipes having cracks or splits.

### 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 46 16

SUBDRAINAGE PIPING  
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 252 (2009; R 2017) Standard Specification for  
Corrugated Polyethylene Drainage Pipe

AASHTO M 288 (2017) Standard Specification for  
Geosynthetic Specification for Highway  
Applications

ASTM INTERNATIONAL (ASTM)

ASTM C33/C33M (2023) Standard Specification for Concrete  
Aggregates

ASTM C136/C136M (2019) Standard Test Method for Sieve  
Analysis of Fine and Coarse Aggregates

ASTM D4491/D4491M (2017) Standard Test Methods for Water  
Permeability of Geotextiles by Permittivity

ASTM D4533 (2011) Trapezoid Tearing Strength of  
Geotextiles

ASTM D4632/D4632M (2015a) Grab Breaking Load and Elongation  
of Geotextiles

ASTM D4751 (2016) Standard Test Method for  
Determining Apparent Opening Size of a  
Geotextile

ASTM D6241 (2014) Standard Test Method for the Static  
Puncture Strength of Geotextiles and  
Geotextile-Related Products Using a 50-mm  
Probe

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-04 Samples

Geotextile

Pipe and Pipe Fittings

SD-07 Certificates

Geotextile

Pipe and Pipe Fittings

1.3 DELIVERY, STORAGE, AND HANDLING

1.3.1 Delivery and Storage

Inspect materials delivered to site for damage; unload, and store with minimum handling. Do not store materials directly on the ground. Keep the inside of pipes and fittings free of dirt and debris. Keep, during shipment and storage, geotextile wrapped in burlap or similar heavy-duty protective covering. Protect the geotextile from mud, soil, dust, and debris. Do not store geotextile materials in direct sunlight. Install plastic pipe within 6 months from the date of manufacture unless otherwise approved.

1.3.2 Handling

Handle materials in such a manner as to ensure delivery to the trench in sound undamaged condition. Carry pipe to the trench.

PART 2 PRODUCTS

2.1 PIPE FOR SUBDRAINS

Submit samples of pipe and pipe fittings, before starting the work. Provide type and sizes of subdrain pipe indicated. Submit certifications from the manufacturers attesting that materials meet specification requirements. Certificates are required for drain pipe and fittings.

2.1.1 Plastic

Provide plastic pipe containing ultraviolet inhibitor to provide protection from exposure to direct sunlight. Provide pipe with bell and spigot or solvent cement joints. Provide manufacturer's standard type fittings conforming to the indicated specification.

2.1.1.1 Corrugated Polyethylene (PE) and Fittings

AASHTO M 252, Type SP as indicated.

2.1.1.2 Pipe Perforations

Provide pipe perforations with a minimum water inlet area of 0.5 square inch per linear foot and as specified below.

2.1.1.2.1 Circular Perforations in Plastic Pipe

Cleanly cut circular holes not more than 3/8 inch or less than 3/16 inch

in diameter and arrange in rows parallel to the longitudinal axis of the pipe. Provide pipe with perforations spaced uniformly along rows. Unless otherwise recommended by the pipe manufacturer, provide pipe with rows approximately 1-1/2 inches apart and arranged in a staggered pattern so that all perforations lie at the midpoint between perforations in adjacent rows. Space the rows over not more than 155 degrees of circumference. Provide pipe that is not perforated for a length equal to the depth of the socket at the spigot or tongue end and provide perforations that continue at uniform spacing over the entire length of the pipe.

2.1.1.2.2 Slotted Perforations in Plastic Pipe

Cleanly cut circumferential slots so as not to restrict the inflow of water and uniformly spaced along the length and circumference of the pipe. Provide pipe with slots not exceeding 1/8 inch nor less than 1/32 inch in width. Provide pipe with individual slot lengths not exceeding 10 percent of the pipe inside nominal circumference on 6 to 8 inch diameter pipe, and 2-1/2 inches on 10 inch diameter pipe. Symmetrically space rows of slots so that they are fully contained in 2 quadrants of the pipe. Center slots in the valleys of the corrugations of profile wall pipe.

2.2 GEOTEXTILE

Provide geotextile conforming to AASHTO M 288 and meeting the subsurface drainage requirements.

Geosynthetics used for filter fabric must be permeable and nonwoven. Filter fabric must be manufactured from polyester, polypropylene, or combined polyester and polypropylene.

Filter fabric must comply with the requirements shown in the following table:

Quality Characteristic	Test Method	Requirements
Permittivity, (min, secl)	ASTM D4491/D4491M	1.5
Apparent Opening Size, average roll value, (Max, US standard sieve size)	ASTM D4751	70
Grab Tensile Strength (min, lb)	ASTM D4632/D4632M	100
Grad Tensile Elongation, (min, percent)	ASTM D4632/D4632M	50



Quality Characteristic	Test Method	Requirements
Puncture Strength, (min, lb)	ASTM D6241	310
Trapezoid Tearing Strength, (min, lb)	ASTM D4533	40

Submit samples of geotextile and certifications from the manufacturers attesting that geotextile meets specification requirements.

2.3 SUBDRAIN FILTER AND BEDDING MATERIAL

Provide subdrain filter and bedding material composed of washed sand, sand and gravel, crushed stone, crushed stone screenings, or slag composed of hard, tough, durable particles free from adherent coatings. Filter material may not contain corrosive agents, organic matter, or soft, friable, thin, or elongated particles. Provide filter material that is evenly graded between the limits specified in TABLE I. Gradation curves will exhibit no abrupt changes in slope denoting skip or gap grading. Provide filter materials that are clean and free from soil and foreign materials. Remove and replace filter blankets found to be dirty or otherwise contaminated with material meeting the specific requirements, at no additional cost to the Government.

	Type I Gradation E 11 ASTM C33/C33M	Type II Gradation 57 ASTM C33/C33M
ASTM C136/C136M Sieve Size	Percent Passing	Percent Passing
1-1/2 inch	--	100
1 inch	--	90 - 100
3/8 inch	100	25 - 60
No. 4	95 - 100	5 - 40
No. 8	--	0 - 20
No. 16	45 - 80	--
No. 50	10 - 30	--
No. 100	0 - 10	--

PART 3 EXECUTION

3.1 EXCAVATION AND BEDDING FOR SUBDRAIN SYSTEMS

Excavate trenches, including the removal of rock and unstable material, in accordance with Section 31 00 00 EARTHWORK. Bedding material shall be

placed in the trench as indicated or as required as replacement materials used in those areas where unstable materials were removed. Compaction of the bedding material shall be as specified for cohesionless material in Section 31 00 00 EARTHWORK.

### 3.2 INSTALLATION OF GEOTEXTILE AND PIPE FOR SUBDRAINS

#### 3.2.1 Installation of Geotextile

##### 3.2.1.1 Trench Lining and Overlaps

Grade trenches to be lined with geotextile to obtain smooth side and bottom surfaces so that the geotextile will not bridge cavities in the soil or be damaged by projecting rock. Lay the geotextile flat but not stretched on the soil, and secure it with anchor pins in accordance with manufacturer's instructions. Overlap 12 inches and secure with anchor pins along the overlaps.

#### 3.2.2 Installation of Pipe for Subdrains

##### 3.2.2.1 Pipelaying

Install pipe in accordance with the manufacturer's recommendations. Thoroughly examine each section of pipe before being laid; do not use defective or damaged pipe. Do not lay pipe when the trench conditions or weather is unsuitable for such work. Remove water from trenches by sump pumping or other approved methods. Lay the pipe to the grades and alignment as indicated. Bed the pipe to the established gradeline. Center perforations on the bottom of the pipe. Lay bell-and-spigot type with the bell ends upstream. Approval of all in-place pipes by the Contracting Officer is required prior to backfilling.

### 3.3 INSTALLATION OF FILTER MATERIAL AND BACKFILLING FOR PERFORATED SUBDRAINS

After perforated pipe for subdrains has been laid, inspected, and approved, place filter material around and over the pipe to the depth indicated. Place the filter material in layers not to exceed 8 inches thick. Thoroughly compact each layer using mechanical tampers or rammers.

-- End of Section --



SECTION 33 71 02

UNDERGROUND ELECTRICAL DISTRIBUTION

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.

ASTM INTERNATIONAL (ASTM)

ASTM B1	(2013) Standard Specification for Hard-Drawn Copper Wire
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 F512	(2019; R 2024) Standard Specification for Smooth-Wall Poly (Vinyl Chloride) (PVC) Conduit and Fittings for Underground Installation

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 C2	(2023) National Electrical Safety Code
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
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NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C119.1	(2023) Electric Connectors - Sealed Insulated Underground Connector Systems Rated 600 Volts
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
NEMA TC 6 & 8	(2020) Standard for Polyvinyl Chloride (PVC) Plastic Utilities Duct for Underground Installations
NEMA TC 9	(2020) Standard for Fittings for Polyvinyl Chloride (PVC) Plastic Utilities Duct for Underground Installation
NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)	
NFPA 70	(2023; ERTA 7 2023; TIA 23-15) National Electrical Code
TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)	
TIA-758	(2012b) Customer-Owned Outside Plant Telecommunications Infrastructure Standard
U.S. DEPARTMENT OF AGRICULTURE (USDA)	
RUS Bull 1751F-644	(2002) Underground Plant Construction
UNDERWRITERS LABORATORIES (UL)	
UL 6	(2022) UL Standard for Safety Electrical Rigid Metal Conduit-Steel
UL 44	(2018; Reprint May 2021) UL Standard for Safety Thermoset-Insulated Wires and Cables
UL 83	(2017; Reprint Mar 2020) UL Standard for Safety Thermoplastic-Insulated Wires and Cables
UL 94	(2023; Reprint Jan 2024) UL Standard for Safety Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
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 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 651	(2011; Reprint May 2022) UL Standard for

Safety Schedule 40, 80, Type EB and A  
Rigid PVC Conduit and Fittings

UL 854 (2020; Reprint Nov 2023) Standard for  
Service-Entrance Cables

UL 1242 (2006; Reprint Apr 2022) UL Standard for  
Safety Electrical Intermediate Metal  
Conduit -- Steel

## 1.2 DEFINITIONS

- a. Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, are as defined in IEEE Stds Dictionary.
- b. In the text of this section, the words conduit and duct are used interchangeably and have the same meaning.

## 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 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

SD-03 Product Data

Conduit, Ducts, and Fittings; G

Low Voltage Insulated Conductors and Cables; G

Low Voltage Wire Connectors and Terminals; G

SD-06 Test Reports

Field Acceptance Checks and Tests; 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 IEEE C2 and 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 2 years prior to bid opening. The 2-year period 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 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 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.

#### 1.4.2.2 Material and Equipment Manufacturing Date

Products manufactured more than 3 years prior to date of delivery to site are not acceptable, unless specified otherwise.

### PART 2 PRODUCTS

#### 2.1 CONDUIT, DUCTS, AND FITTINGS

##### 2.1.1 Rigid Metal Conduit

UL 6.

##### 2.1.1.1 Rigid Metallic Conduit, PVC Coated

NEMA RN 1, Type A40, except that hardness must be nominal 85 Shore A durometer, dielectric strength must be minimum 400 volts per mil at 60 Hz, and tensile strength must be minimum 3500 psi.

##### 2.1.2 Intermediate Metal Conduit

UL 1242.

##### 2.1.2.1 Intermediate Metal Conduit, PVC Coated

NEMA RN 1, Type A40, except that hardness must be nominal 85 Shore A durometer, dielectric strength must be minimum 400 volts per mil at 60 Hz, and tensile strength must be minimum 3500 psi.

##### 2.1.3 Plastic Conduit for Direct Burial and Riser Applications

UL 651 and NEMA TC 2, EPC-40 or EPC-80 as indicated.

##### 2.1.4 Plastic Duct for Concrete Encasement

Provide Type EB-20 per UL 651, ASTM F512, and NEMA TC 6 & 8 or Type EPC-40 per UL 651 and NEMA TC 2, as indicated.

##### 2.1.5 Duct Sealant

UL 94, Class HBF. Provide high-expansion urethane foam duct sealant that

expands and hardens to form a closed, chemically and water resistant, rigid structure. Sealant must be compatible with common cable and wire jackets and capable of adhering to metals, plastics and concrete. Sealant must be capable of curing in temperature ranges of 35 degrees F to 95 degrees F. Cured sealant must withstand temperature ranges of -20 degrees F to 200 degrees F without loss of function.

#### 2.1.6 Fittings

##### 2.1.6.1 Metal Fittings

UL 514B.

##### 2.1.6.2 PVC Conduit Fittings

UL 514B, UL 651.

##### 2.1.6.3 PVC Duct Fittings

NEMA TC 9.

##### 2.1.6.4 Outlet Boxes for Steel Conduit

Outlet boxes for use with rigid or flexible steel conduit must be cast-metal cadmium or zinc-coated if of ferrous metal with gasketed closures and must conform to UL 514A.

#### 2.2 LOW VOLTAGE INSULATED CONDUCTORS AND CABLES

Insulated conductors must be rated 600 volts and conform to the requirements of NFPA 70, including listing requirements. Wires and cables manufactured more than 12 months prior to date of delivery to the site are not acceptable. Service entrance conductors must conform to UL 854, type USE.

##### 2.2.1 Conductor Types

Cable and duct sizes indicated are for copper conductors and THHN/THWN unless otherwise noted. Conductors No. 10 AWG and smaller must be solid. Conductors No. 8 AWG and larger must be stranded. All conductors must be copper.

##### 2.2.2 Conductor Material

Unless specified or indicated otherwise or required by NFPA 70, wires in conduit, other than service entrance, must be 600-volt, Type THWN/THHN conforming to UL 83 or Type XHHW conforming to UL 44. Copper conductors must be annealed copper complying with ASTM B3 and ASTM B8.

##### 2.2.3 Jackets

Provide multiconductor cables with an overall PVC outer jacket.

##### 2.2.4 Cable Marking

Insulated conductors must have the date of manufacture and other identification imprinted on the outer surface of each cable at regular intervals throughout the cable length.



Identify each cable by means of a fiber, laminated plastic, or non-ferrous metal tags in each manhole, handhole, junction box, and each terminal. Each tag must contain the following information; cable type, conductor size, circuit number, circuit voltage, cable destination and phase identification.

Color code conductors. Provide conductor identification within each enclosure where a tap, splice, or termination is made. Conductor identification must be by color-coded insulated conductors, plastic-coated self-sticking printed markers, colored nylon cable ties and plates, heat shrink type sleeves, or colored electrical tape. Properly identify control circuit terminations. Color must be green for grounding conductors and white for neutrals; except where neutrals of more than one system are installed in same raceway or box, other neutrals may be white with a different colored (not green) stripe for each. Color of ungrounded conductors in different voltage systems are 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

### 2.3 LOW VOLTAGE WIRE CONNECTORS AND TERMINALS

Provide a uniform compression over the entire conductor contact surface. Use solderless terminal lugs on stranded conductors.

- a. For use with copper conductors: UL 486A-486B.

### 2.4 LOW VOLTAGE SPLICES

Provide splices in conductors with a compression connector on the conductor and by insulating and waterproofing using one of the following methods which are suitable for continuous submersion in water and comply with ANSI C119.1.

#### 2.4.1 Heat Shrinkable Splice

Provide heat shrinkable splice insulation by means of a thermoplastic adhesive sealant material applied in accordance with the manufacturer's written instructions.

#### 2.4.2 Cold Shrink Rubber Splice

Provide a cold-shrink rubber splice which consists of EPDM rubber tube which has been factory stretched onto a spiraled core which is removed

during splice installation. The installation must not require heat or flame, or any additional materials such as covering or adhesive. It must be designed for use with inline compression type connectors, or indoor, outdoor, direct-burial or submerged locations.

## 2.5 TELECOMMUNICATIONS CABLING

Provide telecommunications cabling in accordance with Section 33 82 00 TELECOMMUNICATIONS OUTSIDE PLANT (OSP).

## 2.6 TAPE

### 2.6.1 Insulating Tape

UL 510, plastic insulating tape, capable of performing in a continuous temperature environment of 80 degrees C.

### 2.6.2 Buried Warning and Identification Tape

Provide detectable tape in accordance with Section 31 00 00 EARTHWORK.

### 2.6.3 Fireproofing Tape

Provide tape composed of a flexible, conformable, unsupported intumescent elastomer. Tape must be not less than .030 inch thick, noncorrosive to cable sheath, self-extinguishing, noncombustible, adhesive-free, and must not deteriorate when subjected to oil, water, gases, salt water, sewage, and fungus.

## 2.7 PULL ROPE

Plastic or flat pull line (bull line) having a minimum tensile strength of 200 pounds.

## 2.8 GROUNDING AND BONDING

### 2.8.1 Driven Ground Rods

Provide copper-clad steel ground rods conforming to UL 467 not less than 3/4 inch in diameter by 10 feet in length. Sectional type rods may be used for rods 20 feet or longer.

### 2.8.2 Grounding Conductors

Stranded-bare copper conductors must conform to ASTM B8, Class B, soft-drawn unless otherwise indicated. Solid-bare copper conductors must conform to ASTM B1 for sizes No. 8 and smaller. Insulated conductors must be of the same material as phase conductors and green color-coded, except that conductors must be rated no more than 600 volts. Aluminum is not acceptable.

## 2.9 CAST-IN-PLACE CONCRETE

Provide concrete in accordance with Section 03 30 00 CAST-IN-PLACE CONCRETE. In addition, provide concrete for encasement of underground ducts with 3000 psi minimum 28-day compressive strength. Concrete associated with electrical work for other than encasement of underground ducts must be 4000 psi minimum 28-day compressive strength unless specified otherwise.

### PART 3 EXECUTION

#### 3.1 INSTALLATION

Install equipment and devices in accordance with the manufacturer's published instructions and with the requirements and recommendations of NFPA 70 and IEEE C2 as applicable. In addition to these requirements, install telecommunications in accordance with TIA-758 and RUS Bull 1751F-644.

#### 3.2 CABLE INSPECTION

Inspect each cable reel for correct storage positions, signs of physical damage, and broken end seals prior to installation. If end seal is broken, remove moisture from cable prior to installation in accordance with the cable manufacturer's recommendations.

#### 3.3 UNDERGROUND FEEDERS SUPPLYING BUILDINGS

Terminate underground feeders supplying building at a point 5 feet outside the building and projections thereof, except that conductors must be continuous to the terminating point indicated. Coordinate connections of the feeders to the service entrance equipment with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide RGS conduit from the supply equipment to a point 5 feet outside the building and projections thereof. Protect ends of underground conduit with plastic plugs until connections are made.

#### 3.4 UNDERGROUND CONDUIT AND DUCT SYSTEMS

##### 3.4.1 Requirements

Run conduit in straight lines except where a change of direction is necessary. Provide numbers and sizes of ducts as indicated. Provide a 4/0 AWG bare copper grounding conductor below medium-voltage distribution duct banks. Bond bare copper grounding conductor to ground rings (loops) in all manholes and to ground rings (loops) at all equipment slabs (pads). Route grounding conductor into manholes with the duct bank (sleeving is not required). Ducts must have a continuous slope downward toward underground structures and away from buildings, laid with a minimum slope of 4 inches per 100 feet. Depending on the contour of the finished grade, the high-point may be at a terminal, a manhole, a handhole, or between manholes or handholes. Terminate all PVC conduit end points in utility holes, switching cabinets, transform handholes and buildings with end bells. The bell end of the conduits that enter manholes and handholes must be flush with the wall.

Perform changes in ductbank direction as follows:

- a. Short-radius manufactured 90-degree duct bends may be used only for pole or equipment risers, unless specifically indicated as acceptable.
- b. The minimum manufactured bend radius must be 18 inches for ducts of less than 3 inch diameter, and 36 inches for ducts 3 inches or greater in diameter.
- c. As an exception to the bend radius required above, provide field manufactured longsweep bends having a minimum radius of 25 feet for a

change of direction of more than 5 degrees, either horizontally or vertically, using a combination of curved and straight sections. Maximum manufactured curved sections allowed for use in field manufactured longsweep bend: 30 degrees.

#### 3.4.2 Treatment

Keep ducts clean of concrete, dirt, or foreign substances during construction. Make field cuts requiring tapers with proper tools and match factory tapers. Use a coupling recommended by the duct manufacturer whenever an existing duct is connected to a duct of different material or shape. Store ducts to avoid warping and deterioration with ends sufficiently plugged to prevent entry of any water or solid substances. Thoroughly clean ducts before being laid. Store plastic ducts on a flat surface and protected from the direct rays of the sun.

#### 3.4.3 Conduit Cleaning

As each conduit run is completed, for conduit sizes 3 inches and larger, draw a flexible testing mandrel approximately 12 inches long with a diameter less than the inside diameter of the conduit through the conduit. After which, draw a stiff bristle brush through until conduit is clear of particles of earth, sand and gravel; then immediately install conduit plugs. For conduit sizes less than 3 inches, draw a stiff bristle brush through until conduit is clear of particles of earth, sand and gravel; then immediately install conduit plugs.

#### 3.4.4 Jacking and Drilling Under Roads and Structures

Conduits to be installed under existing paved areas which are not to be disturbed, and under roads and railroad tracks, must be zinc-coated, rigid steel, jacked into place. Where ducts are jacked under existing pavement, install rigid steel conduit because of its strength. To protect the corrosion-resistant conduit coating, predrilling or installing conduit inside a larger iron pipe sleeve (jack-and-sleeve) is required. For crossings of existing railroads and airfield pavements greater than 50 feet in length, the predrilling method or the jack-and-sleeve method will be used. Separators or spacing blocks must be made of steel, concrete, plastic, or a combination of these materials placed not farther apart than 4 feet on centers.

#### 3.4.5 Galvanized Conduit Concrete Penetrations

Galvanized conduits which penetrate concrete (slabs, pavement, and walls) in wet locations must be PVC coated and extend from at least 2 inches within the concrete to the first coupling or fitting outside the concrete (minimum of 6 inches from penetration).

#### 3.4.6 Multiple Conduits

Separate multiple conduits by a minimum distance of 3 inches, except that light and power conduits must be separated from control, signal, and telephone conduits by a minimum distance of inches. Stagger the joints of the conduits by rows (horizontally) and layers (vertically) to strengthen the conduit assembly. Provide plastic duct spacers that interlock vertically and horizontally. Spacer assembly must consist of base spacers, intermediate spacers, ties, and locking device on top to provide a completely enclosed and locked-in conduit assembly. Install spacers per manufacturer's instructions, but provide a minimum of two spacer

assemblies per 10 feet of conduit assembly.

#### 3.4.7 Conduit Plugs and Pull Rope

Provide new conduit indicated as being unused or empty with plugs on each end. Plugs must contain a weephole or screen to allow water drainage. Provide a plastic pull rope having 3 feet of slack at each end of unused or empty conduits.

#### 3.4.8 Conduit and Duct Without Concrete Encasement

Depths to top of the conduit must be not less than 24 inches below finished grade. Provide not less than 3 inches clearance from the conduit to each side of the trench. Grade bottom of trench smooth; where rock, soft spots, or sharp-edged materials are encountered, excavate the bottom for an additional 3 inches, fill and tamp level with original bottom with sand or earth free from particles, that would be retained on a 1/4 inch sieve. The first 6 inch layer of backfill cover must be sand compacted as previously specified. The rest of the excavation must be backfilled and compacted in 3 to 6 inch layers. Provide color, type and depth of warning tape as specified in Section 31 00 00 EARTHWORK.

##### 3.4.8.1 Encasement Under Roads and Structures

Under roads, paved areas, and railroad tracks, install conduits in concrete encasement of rectangular cross-section providing a minimum of 3 inch concrete cover around ducts. Extend concrete encasement at least 5 feet beyond the edges of paved areas and roads, and 12 feet beyond the rails on each side of railroad tracks. Depths to top of the concrete envelope must be not less than 24 inches below finished grade.

#### 3.4.9 Duct Encased in Concrete

Construct underground duct lines of individual conduits encased in concrete. Depths to top of the concrete envelope must be not less than 18 inches below finished grade, except under roads and pavement, concrete envelope must be not less than 24 inches below finished grade. Do not mix different kinds of conduit in any one duct bank. Concrete encasement surrounding the bank must be rectangular in cross-section and provide at least 3 inches of concrete cover for ducts. Separate conduits by a minimum concrete thickness of 3 inches. Before pouring concrete, anchor duct bank assemblies, prevent floating during concrete pouring by driving reinforcing rods adjacent to duct spacer assemblies and attaching the rods to the spacer assembly. Provide color, type and depth of warning tape as specified in Section 31 00 00 EARTHWORK.

##### 3.4.9.1 Connections to Manholes

Duct bank envelopes connecting to underground structures must be flared to have enlarged cross-section at the manhole entrance to provide additional shear strength. Dimensions of the flared cross-section must be larger than the corresponding manhole opening dimensions by no less than 12 inches in each direction. Perimeter of the duct bank opening in the underground structure must be flared toward the inside or keyed to provide a positive interlock between the duct bank and the wall of the structure. Use vibrators when this portion of the encasement is poured to assure a seal between the envelope and the wall of the structure.

#### 3.4.9.2 Connections to Existing Concrete Pads

For duct bank connections to concrete pads, break an opening in the pad out to the dimensions required and preserve steel in pad. Cut the steel and extend into the duct bank envelope. Chip out the opening in the pad to form a key for the duct bank envelope.

#### 3.4.9.3 Connections to Existing Ducts

Where connections to existing duct banks are indicated, excavate the banks to the maximum depth necessary. Cut off the banks and remove loose concrete from the conduits before new concrete-encased ducts are installed. Provide a reinforced concrete collar, poured monolithically with the new duct bank, to take the shear at the joint of the duct banks.

#### 3.4.9.4 Partially Completed Duct Banks

During construction wherever a construction joint is necessary in a duct bank, prevent debris such as mud, and, and dirt from entering ducts by providing suitable conduit plugs. Fit concrete envelope of a partially completed duct bank with reinforcing steel extending a minimum of 2 feet back into the envelope and a minimum of 2 feet beyond the end of the envelope. Provide one No. 4 bar in each corner, 3 inches from the edge of the envelope. Secure corner bars with two No. 3 ties, spaced approximately one foot apart. Restrain reinforcing assembly from moving during concrete pouring.

#### 3.4.10 Duct Sealing

Seal all electrical penetrations for radon mitigation, maintaining integrity of the vapor barrier, and to prevent infiltration of air, insects, and vermin.

### 3.5 CABLE PULLING

Pull cables down grade with the feed-in point at the manhole or buildings of the highest elevation. Use flexible cable feeds to convey cables through manhole opening and into duct runs. Do not exceed the specified cable bending radii when installing cable under any conditions, including turnups into switches, transformers, switchgear, switchboards, and other enclosures. Cable with tape shield must have a bending radius not less than 12 times the overall diameter of the completed cable. If basket-grip type cable-pulling devices are used to pull cable in place, cut off the section of cable under the grip before splicing and terminating.

#### 3.5.1 Cable Lubricants

Use lubricants that are specifically recommended by the cable manufacturer for assisting in pulling jacketed cables.

### 3.6 CONDUCTORS INSTALLED IN PARALLEL

Group conductors such that each conduit of a parallel run contains one Phase A conductor, one Phase B conductor, one Phase C conductor, and one neutral conductor.

### 3.7 LOW VOLTAGE CABLE SPLICING AND TERMINATING

Make terminations and splices with materials and methods as indicated or

specified herein and as designated by the written instructions of the manufacturer. Do not allow the cables to be moved until after the splicing material has completely set. Make splices in underground distribution systems only in accessible locations such as manholes, handholes, or aboveground termination pedestals.

### 3.8 CABLE END CAPS

Cable ends must be sealed at all times with coated heat shrinkable end caps. Cable ends must be sealed when the cable is delivered to the job site, while the cable is stored and during installation of the cable. The caps must remain in place until the cable is spliced or terminated. Sealing compounds and tape are not acceptable substitutes for heat shrinkable end caps. Cable which is not sealed in the specified manner at all times will be rejected.

### 3.9 GROUNDING SYSTEMS

NFPA 70 and IEEE C2, except provide grounding systems with a resistance to solid earth ground not exceeding 5 ohms.

#### 3.9.1 Grounding Electrodes

Provide cone pointed driven ground rods driven full depth plus 6 inches, installed to provide an earth ground of the appropriate value for the particular equipment being grounded.

If the specified ground resistance is not met, provide an additional ground rod in accordance with the requirements of NFPA 70 (placed not less than 6 feet from the first rod). Should the resultant (combined) resistance exceed the specified resistance, measured not less than 48 hours after rainfall, notify the Contracting Officer immediately.

#### 3.9.2 Grounding Connections

Make grounding connections which are buried or otherwise normally inaccessible, by exothermic weld or 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 compression connections using a hydraulic compression tool to provide the correct circumferential pressure. Tools and dies must be as recommended by the manufacturer. An embossing die code or other standard method must provide visible indication that a connector has been adequately compressed on the ground wire.

#### 3.9.3 Grounding Conductors

Provide bare grounding conductors, except where installed in conduit with associated phase conductors. Ground cable sheaths, cable shields, conduit, and equipment with No. 6 AWG. Ground other noncurrent-carrying metal parts and equipment frames of metal-enclosed equipment. Ground metallic frames and covers of handholes and pull boxes with a braided, copper ground strap with equivalent ampacity of No. 6 AWG.

### 3.9.4 Ground Cable Crossing Expansion Joints

Protect ground cables crossing expansion joints or similar separations in structures and pavements by use of approved devices or methods of installation which provide the necessary slack in the cable across the joint to permit movement. Use stranded or other approved flexible copper cable across such separations.

### 3.9.5 Fence Grounding

Provide grounding for fences with a ground rod at each fixed gate post and at each corner post. Drive ground rods until the top is 12 inches below grade. Attach a No. 4 AWG copper conductor, by exothermic weld to the ground rods and extend underground to the immediate vicinity of fence post. Lace the conductor vertically into 12 inches of fence mesh and fasten by two approved bronze compression fittings, one to bond wire to post and the other to bond wire to fence. Bond each gate section to its gatepost by a 1/8 by one inch flexible braided copper strap and ground post clamps. Clamps must be of the anti-electrolysis type.

## 3.10 EXCAVATING, BACKFILLING, AND COMPACTING

Provide in accordance with NFPA 70 and Section 31 00 00 EARTHWORK.

### 3.10.1 Reconditioning of Surfaces

#### 3.10.1.1 Unpaved Surfaces

Restore to their original elevation and condition unpaved surfaces disturbed during installation of duct . Preserve sod and topsoil removed during excavation and reinstall after backfilling is completed. Replace sod that is damaged by sod of quality equal to that removed. When the surface is disturbed in a newly seeded area, re-seed the restored surface with the same quantity and formula of seed as that used in the original seeding, and provide topsoiling, fertilizing, liming, seeding, sodding, sprigging, or mulching.

#### 3.10.1.2 Paving Repairs

Where trenches, pits, or other excavations are made in existing roadways and other areas of pavement where surface treatment of any kind exists , restore such surface treatment or pavement the same thickness and in the same kind as previously existed, except as otherwise specified, and to match and tie into the adjacent and surrounding existing surfaces.

## 3.11 CAST-IN-PLACE CONCRETE

Provide concrete in accordance with Section 03 30 00 CAST-IN-PLACE CONCRETE.

### 3.11.1 Concrete Slabs (Pads) for Equipment

Unless otherwise indicated, the slab must be at least 8 inches thick, reinforced with a 6 by 6 - W2.9 by W2.9 mesh, placed uniformly 4 inches from the top of the slab. Place slab on a 6 inch thick, well-compacted gravel base. Top of concrete slab must be approximately 4 inches above finished grade with gradual slope for drainage. Edges above grade must have 1/2 inch chamfer. Slab must be 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 transformer cable training areas.

### 3.12 FIELD QUALITY CONTROL

#### 3.12.1 Performance of Field 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.

##### 3.12.1.1 Low Voltage Cables, 600-Volt

Perform tests after installation of cable, splices and terminations and before terminating to equipment or splicing to existing circuits.

###### a. Visual and Mechanical Inspection

- (1) Inspect exposed cable sections for physical damage.
- (2) Verify that cable is supplied and connected in accordance with contract plans and specifications.
- (3) Verify tightness of accessible bolted electrical connections.
- (4) Inspect compression-applied connectors for correct cable match and indentation.
- (5) Visually inspect jacket and insulation condition.
- (6) Inspect for proper phase identification and arrangement.

###### b. Electrical Tests

- (1) Perform insulation resistance tests on wiring No. 6 AWG and larger diameter using instrument which applies voltage of approximately 1000 volts dc for one minute.
- (2) Perform continuity tests to insure correct cable connection.

##### 3.12.1.2 Grounding System

###### a. Visual and mechanical inspection

Inspect ground system for compliance with contract plans and specifications.

###### b. Electrical tests

Perform ground-impedance measurements utilizing the fall-of-potential method in accordance with IEEE 81. 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. The instrument must be 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. Provide site diagram indicating location of test probes with associated distances, and provide a plot of resistance vs. distance.

### 3.12.2 Follow-Up Verification

Upon completion of acceptance checks and tests, show by demonstration in service that circuits and devices are in good operating condition and properly performing the intended function. As an exception to requirements stated elsewhere in the contract, the Contracting Officer must be given 5 working days advance notice of the dates and times of checking and testing.

.... -- 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 (2023) 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	(2020c) 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	(2023d) OFSTP-14A Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant
TIA-526-7	(2015a; R 2022) Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant, Adoption of IEC 61280-4-2 edition 2: Fibre-Optic Communications Subsystem Test Procedures - Part 4-2: Installed Cable Plant - Single-Mode Attenuation and Optical Return Loss Measurement
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 2022) UL Standard for Safety 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. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY 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,  $A > 10kA$ ,  $B > 400$ ,  $C > 65A$  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 (2015) 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" or "S" classification. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

### SD-03 Product Data

Separator

### SD-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 14.00 10 CATHODIC PROTECTION SYSTEM (SACRIFICIAL ANODE) 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 --



