

SECTION 230513 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes general requirements for single-phase and polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on alternating-current power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation.

1.3 COORDINATION

- A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:
 - 1. Motor controllers.
 - 2. Torque, speed, and horsepower requirements of the load.
 - 3. Ratings and characteristics of supply circuit and required control sequence.
 - 4. Ambient and environmental conditions of installation location.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

- A. Comply with NEMA MG 1 unless otherwise indicated.

2.2 MOTOR CHARACTERISTICS

- A. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet above sea level.
- B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

2.3 POLYPHASE MOTORS

- A. Description: NEMA MG 1, Design B, medium induction motor.
- B. Efficiency: Premium efficient, as defined in NEMA MG 1.
- C. Service Factor: 1.15.

- D. Multispeed Motors: Variable torque.
 - 1. For motors with 2:1 speed ratio, consequent pole, single winding.
- E. Rotor: Random-wound, squirrel cage.
- F. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.
- G. Temperature Rise: Match insulation rating.
- H. Insulation: Class F.
- I. Code Letter Designation:
 - 1. Motors 15 HP and Larger: NEMA starting Code F or Code G.
 - 2. Motors Smaller Than 15 HP: Manufacturer's standard starting characteristic.
- J. Enclosure Material: Cast iron for motor frame sizes 324T and larger; rolled steel for motor frame sizes smaller than 324T.

2.4 ADDITIONAL REQUIREMENTS FOR POLYPHASE MOTORS

- A. Motors Used with Variable-Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.
 - 1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width-modulated inverters.
 - 2. Premium-Efficient Motors: Class B temperature rise; Class F insulation.
 - 3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
 - 4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

2.5 SINGLE-PHASE MOTORS

- A. Motors larger than 1/20 hp shall be one of the following, to suit starting torque and requirements of specific motor application:
 - 1. Permanent-split capacitor.
- B. Multispeed Motors: Variable-torque, permanent-split-capacitor type.
- C. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.
- D. Motors 1/20 HP and Smaller: Shaded-pole type.
- E. Thermal Protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 230513

SECTION 230516 - EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Packed expansion joints.
 - 2. Alignment guides and anchors.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
- B. Delegated-Design Submittal: For each anchor and alignment guide, including analysis data, signed and sealed by the qualified professional engineer responsible for their preparation.
 - 1. Design Calculations: Calculate requirements for thermal expansion of piping systems and for selecting and designing expansion joints, loops, and swing connections.
 - 2. Anchor Details: Detail fabrication of each anchor indicated. Show dimensions and methods of assembly and attachment to building structure.
 - 3. Alignment Guide Details: Detail field assembly and attachment to building structure.
 - 4. Schedule: Indicate type, manufacturer's number, size, material, pressure rating, end connections, and location for each expansion joint.

1.4 QUALITY ASSURANCE

- A. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Pipe and Pressure-Vessel Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Compatibility: Products shall be suitable for piping service fluids, materials, working pressures, and temperatures.
- B. Capability: Products to absorb 200 percent of maximum axial movement between anchors.

2.2 PACKLESS EXPANSION JOINTS

A. Metal-Bellows Packless Expansion Joints :

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Flex-Hose Co., Inc.
 - b. Flex-Pression.
 - c. Flexicraft Industries.
 - d. Hyspan Precision Products, Inc.
 - e. Metraflex Company (The).
 - f. WahlcoMetroflex.
2. Standards: ASTM F1120 and EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."
3. Type: Circular, corrugated bellows with external tie rods.
4. Minimum Pressure Rating: 175 psig, unless otherwise indicated.
5. Configuration: double joint with base class(es), unless otherwise indicated.
6. Expansion Joints for Copper Tubing: multi-ply phosphor-bronze bellows, copper pipe ends, and brass shrouds.
 - a. End Connections for Copper Tubing NPS 2 and Smaller: Solder joint.
 - b. End Connections for Copper Tubing NPS 2-1/2 to NPS 4: Solder joint.
 - c. End Connections for Copper Tubing NPS 5 and Larger: Flanged.
7. Expansion Joints for Steel Piping: multi-ply stainless-steel bellows, steel pipe ends, and carbon-steel shroud.
 - a. End Connections for Steel Pipe NPS 2 and Smaller: Threaded.
 - b. End Connections for Steel Pipe NPS 2-1/2 and Larger: Flanged Welded.

2.3 ALIGNMENT GUIDES AND ANCHORS

A. Alignment Guides :

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Advanced Thermal Systems, Inc.
 - b. Amber/Booth Company, Inc.; a VMC Group Company.
 - c. Flex-Hose Co., Inc.
 - d. Flex-Pression.
 - e. Flexicraft Industries.
 - f. Hyspan Precision Products, Inc.
2. Description: Steel, factory-fabricated alignment guide, with bolted two-section outer cylinder and base for attaching to structure; with two-section guiding slider for bolting to pipe.

B. Anchor Materials:

1. Steel Shapes and Plates: ASTM A36/A36M.
2. Bolts and Nuts: ASME B18.10 or ASTM A183, steel hex head.
3. Washers: ASTM F844, steel, plain, flat washers.

4. Mechanical Fasteners: Insert-wedge-type stud with expansion plug anchor for use in hardened portland cement concrete, with tension and shear capacities appropriate for application.
 - a. Stud: Threaded, zinc-coated carbon steel.
 - b. Expansion Plug: Zinc-coated steel.
 - c. Washer and Nut: Zinc-coated steel.

PART 3 - EXECUTION

3.1 INSTALLATION OF EXPANSION JOINTS

- A. Install expansion joints of sizes matching sizes of piping in which they are installed.
- B. Install packed-type expansion joints with packing suitable for fluid service.
- C. Install metal-bellows expansion joints according to EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."

3.2 INSTALLATION OF ALIGNMENT GUIDES AND ANCHORS

- A. Install alignment guides to guide expansion and to avoid end-loading and torsional stress.
- B. Install one guide(s) on each side of pipe expansion fittings and loops. Install guides nearest to expansion joint not more than four pipe diameters from expansion joint.
- C. Attach guides to pipe, and secure guides to building structure.
- D. Install anchors at locations to prevent stresses from exceeding those permitted by ASME B31.9 and to prevent transfer of loading and stresses to connected equipment.
- E. Anchor Attachments:
 1. Anchor Attachment to Steel Pipe: Attach by welding. Comply with ASME B31.9 and ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
 2. Anchor Attachment to Copper Tubing: Attach with pipe hangers. Use MSS SP-69, Type 24; U bolts bolted to anchor.
- F. Fabricate and install steel anchors by welding steel shapes, plates, and bars. Comply with ASME B31.9 and AWS D1.1/D1.1M.
 1. Anchor Attachment to Steel Structural Members: Attach by welding.
 2. Anchor Attachment to Concrete Structural Members: Attach by fasteners. Follow fastener manufacturer's written instructions.
- G. Use grout to form flat bearing surfaces for guides and anchors attached to concrete.

END OF SECTION 230516

SECTION 230517 - SLEEVES AND SLEEVE SEALS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Sleeves.
 - 2. Stack-sleeve fittings.
 - 3. Sleeve-seal systems.
 - 4. Sleeve-seal fittings.
 - 5. Silicone sealants.
- B. Related Requirements:
 - 1. Section 078413 "Penetration Firestopping" for penetration firestopping installed in fire-resistance-rated walls, horizontal assemblies, and smoke barriers, with and without penetrating items.

PART 2 - PRODUCTS

2.1 SLEEVES

- A. Cast-Iron Pipe Sleeves: Cast or fabricated of cast or ductile iron and equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop collar.
- B. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, anti-corrosion coated or zinc coated, with plain ends and integral welded waterstop collar.
- C. Galvanized-Steel Sheet Sleeves: 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint.
- D. PVC Pipe Sleeves: ASTM D 1785, Schedule 40.
- E. Molded-PVC Sleeves: With nailing flange for attaching to wooden forms.
- F. Molded-PE or -PP Sleeves: Removable, tapered-cup shaped, and smooth outer surface with nailing flange for attaching to wooden forms.

2.2 STACK-SLEEVE FITTINGS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Jay R. Smith Mfg Co; a division of Morris Group International.
 2. Zurn Industries, LLC.
- B. Description: Manufactured, Dura-coated or Duco-coated galvanized cast-iron sleeve with integral cast flashing flange for use in waterproof floors and roofs. Include clamping ring, bolts, and nuts for membrane flashing.
1. Underdeck Clamp: Clamping ring with setscrews.

2.3 SLEEVE-SEAL SYSTEMS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. CALPICO, Inc.
 2. GPT; an EnPro Industries company.
 3. Metraflex Company (The).
- B. Description:
1. Modular sealing-element unit, designed for field assembly, for filling annular space between piping and sleeve.
 2. Designed to form a hydrostatic seal of 20-psig.
 3. Sealing Elements: EPDM-rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size.
 4. Pressure Plates: Carbon steel.
 5. Connecting Bolts and Nuts: Carbon steel, with corrosion-resistant coating, ASTM B 633 of length required to secure pressure plates to sealing elements.

2.4 SLEEVE-SEAL FITTINGS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. CALPICO, Inc.
 2. GPT; an EnPro Industries company.
 3. Metraflex Company (The).
- B. Description:
1. Manufactured plastic, sleeve-type, waterstop assembly, made for imbedding in concrete slab or wall.
 2. Plastic or rubber waterstop collar with center opening to match piping OD.

2.5 SILICONE SEALANTS

- A. Silicone, S, NS, 25, NT: Single-component, nonsag, plus 25 percent and minus 25 percent movement capability, nontraffic-use, neutral-curing silicone joint sealant, ASTM C 920, Type S, Grade NS, Class 25, use NT.
 - 1. Verify sealant has a VOC content of 250 g/L or less.
 - 2. Verify sealant complies with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."
- B. Silicone, S, P, 25, T, NT: Single-component, pourable, plus 25 percent and minus 25 percent movement capability, traffic- and nontraffic-use, neutral-curing silicone joint sealant; ASTM C 920, Type S, Grade P, Class 25, Uses T and NT. Grade P Pourable (self-leveling) formulation is for opening in floors and other horizontal surfaces that are not fire rated.
 - 1. Verify sealant has a VOC content of 250 g/L or less.
 - 2. Verify sealant complies with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."
- C. Silicone Foam: Multicomponent, silicone-based liquid elastomers that, when mixed, expand and cure in place to produce a flexible, nonshrinking foam.
 - 1. Verify sealant has a VOC content of 250 g/L or less.
 - 2. Verify sealant complies with the testing and product requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."

PART 3 - EXECUTION

3.1 SLEEVE INSTALLATION

- A. Install sleeves for piping passing through penetrations in floors, partitions, roofs, and walls.
- B. For sleeves that will have sleeve-seal system installed, select sleeves of size large enough to provide 1-inch annular clear space between piping and concrete slabs and walls.
 - 1. Sleeves are not required for core-drilled holes.
- C. Install sleeves in concrete floors, concrete roof slabs, and concrete walls as new slabs and walls are constructed.
 - 1. Permanent sleeves are not required for holes in slabs formed by molded-PE or -PP sleeves.
 - 2. Cut sleeves to length for mounting flush with both surfaces.
 - a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 2 inches above finished floor level.
 - 3. Using grout or silicone sealant, seal space outside of sleeves in slabs and walls without sleeve-seal system.

- D. Install sleeves for pipes passing through interior partitions.
 - 1. Cut sleeves to length for mounting flush with both surfaces.
 - 2. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
 - 3. Seal annular space between sleeve and piping or piping insulation; use sealants appropriate for size, depth, and location of joint.
- E. Fire-Resistance-Rated Penetrations, Horizontal Assembly Penetrations, and Smoke-Barrier Penetrations: Maintain indicated fire or smoke rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with fire- and smoke-stop materials. Comply with requirements for firestopping and fill materials specified in Section 078413 "Penetration Firestopping."

3.2 STACK-SLEEVE-FITTING INSTALLATION

- A. Install stack-sleeve fittings in new slabs as slabs are constructed.
 - 1. Install fittings that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
 - 2. Secure flashing between clamping flanges for pipes penetrating floors with membrane waterproofing. Comply with requirements for flashing specified in Section 076200 "Sheet Metal Flashing and Trim."
 - 3. Install section of cast-iron soil pipe to extend sleeve to 3 inches above finished floor level.
 - 4. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified.
 - 5. Using waterproof silicone sealant, seal space between top hub of stack-sleeve fitting and pipe.
- B. Fire-Resistance-Rated, Horizontal Assembly, and Smoke Barrier Penetrations: Maintain indicated fire or smoke rating of floors at pipe penetrations. Seal pipe penetrations with fire- and smoke-stop materials. Comply with requirements for firestopping specified in Section 078413 "Penetration Firestopping."

3.3 SLEEVE-SEAL-SYSTEM INSTALLATION

- A. Install sleeve-seal systems in sleeves in exterior concrete walls and slabs-on-grade at service piping entries into building.
- B. Select type, size, and number of sealing elements required for piping material and size and for sleeve ID or hole size. Position piping in center of sleeve. Center piping in penetration, assemble sleeve-seal-system components, and install in annular space between piping and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make a watertight seal.

3.4 SLEEVE-SEAL-FITTING INSTALLATION

- A. Install sleeve-seal fittings as new walls and slabs are constructed.
- B. Assemble fitting components of length to be flush with both surfaces of concrete slabs and walls. Position waterstop flange to be centered in concrete slab or wall.
- C. Secure nailing flanges to concrete forms.
- D. Using grout or silicone sealant, seal space around outside of sleeve-seal fittings.

3.5 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
 - 1. Leak Test: After allowing for a full cure, test sleeves and sleeve seals for leaks. Repair leaks and retest until no leaks exist.
- B. Sleeves and sleeve seals will be considered defective if they do not pass tests and inspections.

3.6 SLEEVE AND SLEEVE-SEAL SCHEDULE

- A. Use sleeves and sleeve seals for the following piping-penetration applications:
 - 1. Exterior Concrete Walls Above Grade:
 - a. Piping Smaller Than NPS 6 : Steel pipe sleeves.
 - b. Piping NPS 6 and Larger: Steel pipe sleeves.
 - 2. Exterior Concrete Walls Below Grade:
 - a. Piping Smaller Than NPS 6 : Steel pipe sleeves with sleeve-seal system.
 - 1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
 - b. Piping NPS 6 and Larger: Steel pipe sleeves with sleeve-seal system.
 - 1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
 - 3. Concrete Slabs Above Grade:
 - a. Piping Smaller Than NPS 6 : Steel pipe sleeves.
 - b. Piping NPS 6 and Larger: Steel pipe sleeves.
 - 4. Interior Partitions:
 - a. Piping Smaller Than NPS 6 : Steel pipe sleeves.
 - b. Piping NPS 6 and Larger: Galvanized-steel sheet sleeves.

END OF SECTION 230517

SECTION 230518 - ESCUTCHEONS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Escutcheons.

1.3 DEFINITIONS

- A. Existing Piping to Remain: Existing piping that is not to be removed and that is not otherwise indicated to be removed, removed and salvaged, or removed and reinstalled.

PART 2 - PRODUCTS

2.1 ESCUTCHEONS

- A. One-Piece, Steel Type: With polished, chrome-plated finish and setscrew fastener.
- B. One-Piece, Stainless-Steel Type: With polished stainless-steel finish.
- C. One-Piece, Cast-Brass Type: With polished, chrome-plated finish and setscrew fastener.
- D. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with polished, chrome-plated finish and spring-clip fasteners.
- E. One-Piece, Stamped-Steel Type: With polished, chrome-plated finish and spring-clip fasteners.
- F. Split-Plate, Stamped-Steel Type: With polished, chrome-plated finish; concealed hinge; and spring-clip fasteners.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install escutcheons for piping penetrations of walls, ceilings, and finished floors.

- B. Install escutcheons with ID to closely fit around pipe, tube, and insulation of piping and with OD that completely covers opening.
1. Escutcheons for New Piping:
- a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep pattern.
 - b. Insulated Piping: One-piece steel with polished, chrome-plated finish.
 - c. Insulated Piping: One-piece stainless steel with polished stainless-steel finish.
 - d. Insulated Piping: One-piece cast brass with polished, chrome-plated finish.
 - e. Insulated Piping: One-piece stamped steel or split-plate, stamped steel with concealed hinge with polished, chrome-plated finish.
 - f. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece steel with polished, chrome-plated finish.
 - g. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece stainless steel with polished stainless-steel finish.
 - h. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece cast brass with polished, chrome-plated finish.
 - i. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece stamped steel or split-plate, stamped steel with concealed hinge with polished, chrome-plated finish.
 - j. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece steel with polished, chrome-plated finish.
 - k. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece stainless steel with polished stainless-steel finish.
 - l. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece cast brass with polished, chrome-plated finish.
 - m. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece stamped steel or split-plate, stamped steel with concealed hinge with polished, chrome-plated finish.
 - n. Bare Piping in Unfinished Service Spaces: One-piece steel with polished, chrome-plated finish.
 - o. Bare Piping in Unfinished Service Spaces: One-piece cast brass with polished, chrome-plated finish.
 - p. Bare Piping in Equipment Rooms: One-piece steel with polished, chrome-plated finish.
 - q. Bare Piping in Equipment Rooms: One-piece cast brass with polished, chrome-plated finish.

END OF SECTION 230518

SECTION 230519 - METERS AND GAGES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Bimetallic-actuated thermometers.
2. Thermowells.
3. Dial-type pressure gages.
4. Gage attachments.
5. Test plugs.
6. Sight flow indicators.
7. Flowmeters.
8. Thermal-energy meters.

- B. Related Requirements:

1. Section 231123 "Facility Natural-Gas Piping" for gas meters.
2. Section 232216 "Steam and Condensate Piping Specialties" for steam and condensate meters.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1 BIMETALLIC-ACTUATED THERMOMETERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ashcroft Inc.
2. Marsh.
3. Palmer Wahl Instrumentation Group.
4. Taylor.
5. Terrice, H. O. Co.
6. Weiss Instruments, Inc.
7. Weksler Glass Thermometer Corp.

- B. Standard: ASME B40.200.

- C. Case: sealed type(s); stainless steel with 3-inch nominal diameter.

- D. Dial: Nonreflective aluminum with permanently etched scale markings and scales in deg F.
- E. Connector Type(s): Union joint, adjustable angle , with unified-inch screw threads.
- F. Connector Size: 1/2 inch , with ASME B1.1 screw threads.
- G. Stem: 0.25 or 0.375 inch in diameter; stainless steel.
- H. Window: Plain glass.
- I. Ring: Stainless steel.
- J. Element: Bimetal coil.
- K. Pointer: Dark-colored metal.
- L. Accuracy: Plus or minus 1 percent of scale range.

2.2 LIQUID-IN-GLASS THERMOMETERS

A. Metal-Case, Compact-Style, Liquid-in-Glass Thermometers:

- 1. Standard: ASME B40.200.
- 2. Case: Cast aluminum ; 6-inch nominal size.
- 3. Case Form: Back angle unless otherwise indicated.
- 4. Tube: Glass with magnifying lens and blue or red organic liquid.
- 5. Tube Background: Nonreflective aluminum with permanently etched scale markings graduated in deg F.
- 6. Window: Glass or plastic.
- 7. Stem: Aluminum or brass and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
- 8. Connector: 3/4 inch, with ASME B1.1 screw threads.
- 9. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

B. Metal-Case, Industrial-Style, Liquid-in-Glass Thermometers:

- 1. Standard: ASME B40.200.
- 2. Case: Cast aluminum ; 7-inch nominal size unless otherwise indicated.
- 3. Case Form: Back angle unless otherwise indicated.
- 4. Tube: Glass with magnifying lens and blue or red organic liquid.
- 5. Tube Background: Nonreflective aluminum with permanently etched scale markings graduated in deg F.
- 6. Window: Glass.
- 7. Stem: Aluminum and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
- 8. Connector: 1-1/4 inches, with ASME B1.1 screw threads.

9. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

2.3 THERMOWELLS

A. Thermowells:

1. Standard: ASME B40.200.
2. Description: Pressure-tight, socket-type fitting made for insertion in piping tee fitting.
3. Material for Use with Copper Tubing: CNR or CUNI.
4. Material for Use with Steel Piping: CRES.
5. Type: Stepped shank unless straight or tapered shank is indicated.
6. External Threads: NPS 1/2, NPS 3/4, or NPS 1, ASME B1.20.1 pipe threads.
7. Internal Threads: 1/2, 3/4, and 1 inch, with ASME B1.1 screw threads.
8. Bore: Diameter required to match thermometer bulb or stem.
9. Insertion Length: Length required to match thermometer bulb or stem.
10. Lagging Extension: Include on thermowells for insulated piping and tubing.
11. Bushings: For converting size of thermowell's internal screw thread to size of thermometer connection.

B. Heat-Transfer Medium: Mixture of graphite and glycerin.

2.4 DIAL-TYPE PRESSURE GAGES

A. Direct-Mounted, Metal-Case, Dial-Type Pressure Gages:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ashcroft Inc.
 - b. Marsh Bellofram.
 - c. Trerice, H. O. Co.
 - d. Weiss Instruments, Inc.
 - e. Weksler Glass Thermometer Corp.
2. Standard: ASME B40.100.
3. Case: Liquid-filled type(s); cast aluminum or drawn steel ; 4-1/2-inch nominal diameter.
4. Pressure-Element Assembly: Bourdon tube unless otherwise indicated.
5. Pressure Connection: Brass, with NPS 1/2, ASME B1.20.1 pipe threads and bottom-outlet type unless back-outlet type is indicated.
6. Movement: Mechanical, with link to pressure element and connection to pointer.
7. Dial: Nonreflective aluminum with permanently etched scale markings graduated in psi.
8. Pointer: Dark-colored metal.
9. Window: Glass.
10. Ring: Stainless steel.
11. Accuracy: Grade A, plus or minus 1 percent of middle half of scale range.

2.5 GAGE ATTACHMENTS

- A. Snubbers: ASME B40.100, brass; with NPS 1/2, ASME B1.20.1 pipe threads and piston -type surge-dampening device. Include extension for use on insulated piping.
- B. Siphons: Loop-shaped section of steel pipe with NPS 1/2 pipe threads.

- C. Valves: Brass or stainless-steel needle, with NPS 1/2, ASME B1.20.1 pipe threads.

2.6 TEST PLUGS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Fairfax.
 - 2. IMI Flow Design, Inc.
 - 3. Peterson Equipment Co., Inc.
 - 4. Sisco Manufacturing Company, Inc.
- B. Description: Test-station fitting made for insertion in piping tee fitting.
- C. Body: Brass or stainless steel with core inserts and gasketed and threaded cap. Include extended stem on units to be installed in insulated piping.
- D. Thread Size: NPS 1/2, ASME B1.20.1 pipe thread.
- E. Minimum Pressure and Temperature Rating: 500 psig at 200 deg F.
- F. Core Inserts: Chlorosulfonated polyethylene synthetic and EPDM self-sealing rubber.

2.7 SIGHT FLOW INDICATORS

- A. Description: Piping inline-installation device for visual verification of flow.
- B. Construction: Bronze or stainless-steel body, with sight glass and ball, flapper, or paddle wheel indicator, and threaded or flanged ends.
- C. Minimum Pressure Rating: 150 psig.
- D. Minimum Temperature Rating: 200 deg F.
- E. End Connections for NPS 2 and Smaller: Threaded.
- F. End Connections for NPS 2-1/2 and Larger: Flanged.

2.8 FLOWMETERS

- A. Venturi Flowmeters:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Bailey.
 - b. Barco.
 - c. BIF.
 - d. Victaulic Company.
 - 2. Description: Flowmeter with calibrated flow-measuring element, hoses or tubing, fittings, valves, indicator, and conversion chart.
 - 3. Flow Range: Sensor and indicator shall cover operating range of equipment or system served.

4. Sensor: Venturi-type, calibrated, flow-measuring element; for installation in piping.
 - a. Design: Differential-pressure-type measurement for water.
 - b. Construction: Bronze, brass, or factory-primed steel, with brass fittings and attached tag with flow conversion data.
 - c. Minimum Pressure Rating: 250 psig.
 - d. Minimum Temperature Rating: 250 deg F.
 - e. End Connections for NPS 2 and Smaller: Threaded.
 - f. End Connections for NPS 2-1/2 and Larger: Flanged or welded.
 - g. Flow Range: Flow-measuring element and flowmeter shall cover operating range of equipment or system served.
5. Permanent Indicators: Meter suitable for wall or bracket mounting, calibrated for connected flowmeter element, and having 6-inch- diameter, or equivalent, dial with fittings and copper tubing for connecting to flowmeter element.
 - a. Scale: Gallons per minute.
 - b. Accuracy: Plus or minus 1 percent between 20 and 80 percent of scale range.
6. Portable Indicators: Hand-held, differential-pressure type, calibrated for connected flowmeter element and having two 12-foot hoses, with carrying case.
 - a. Scale: Gallons per minute.
 - b. Accuracy: Plus or minus 2 percent between 20 and 80 percent of scale range.
7. Display: Shows rate of flow , with register to indicate total volume in gallons.
8. Conversion Chart: Flow rate data compatible with sensor.
9. Operating Instructions: Include complete instructions with each flowmeter.

2.9 THERMAL-ENERGY METERS

A. Ultrasonic, Thermal-Energy Meters:

1. Description: Meter with flow sensor, temperature sensors, transmitter, indicator, and connecting wiring.
2. Flow Sensor: Transit-time ultrasonic type with transmitter.
3. Temperature Sensors: Insertion-type or strap-on transducer.
4. Indicator: Solid-state, integrating-type meter with integral battery pack.
 - a. Data Output: Six-digit electromechanical counter with readout in kilowatts per hour or British thermal units.
 - b. Battery Pack: Five-year lithium battery.
5. Accuracy: Plus or minus 1 percent.
6. Display: Visually indicates total fluid volume in gallons and thermal-energy flow in kilowatts per hour or British thermal units.
7. Operating Instructions: Include complete instructions with each thermal-energy meter system.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install thermowells with socket extending to center of pipe and in vertical position in piping tees.
- B. Install thermowells of sizes required to match thermometer connectors. Include bushings if required to match sizes.
- C. Install thermowells with extension on insulated piping.
- D. Fill thermowells with heat-transfer medium.
- E. Install direct-mounted thermometers in thermowells and adjust vertical and tilted positions.
- F. Install remote-mounted thermometer bulbs in thermowells and install cases on panels; connect cases with tubing and support tubing to prevent kinks. Use minimum tubing length.
- G. Install duct-thermometer mounting brackets in walls of ducts. Attach to duct with screws.
- H. Install direct-mounted pressure gages in piping tees with pressure gage located on pipe at the most readable position.
- I. Install remote-mounted pressure gages on panel.
- J. Install valve and snubber in piping for each pressure gage for fluids (except steam).
- K. Install valve and syphon fitting in piping for each pressure gage for steam.
- L. Install test plugs in piping tees.
- M. Install flow indicators in piping systems in accessible positions for easy viewing.
- N. Assemble and install connections, tubing, and accessories between flow-measuring elements and flowmeters according to manufacturer's written instructions.
- O. Install flowmeter elements in accessible positions in piping systems.
- P. Install differential-pressure-type flowmeter elements, with at least minimum straight lengths of pipe, upstream and downstream from element according to manufacturer's written instructions.
- Q. Install permanent indicators on walls or brackets in accessible and readable positions.
- R. Install connection fittings in accessible locations for attachment to portable indicators.
- S. Mount thermal-energy meters on wall if accessible; if not, provide brackets to support meters.
- T. Install thermometers in the following locations:
 - 1. Inlet and outlet of each hydronic boiler.
 - 2. Two inlets and two outlets of each chiller.
 - 3. Inlet and outlet of each hydronic coil in air-handling units.
 - 4. Insert Location.

- U. Install pressure gages in the following locations:
 - 1. Inlet and outlet of each chiller chilled-water and condenser-water connection.
 - 2. Suction and discharge of each pump.
 - 3. Insert Location.

3.2 CONNECTIONS

- A. Install meters and gages adjacent to machines and equipment to allow space for service and maintenance of meters, gages, machines, and equipment.
- B. Connect flowmeter-system elements to meters.
- C. Connect flowmeter transmitters to meters.
- D. Connect thermal-energy meter transmitters to meters.

3.3 ADJUSTING

- A. After installation, calibrate meters according to manufacturer's written instructions.
- B. Adjust faces of meters and gages to proper angle for best visibility.

3.4 THERMOMETER SCHEDULE

- A. Thermometers at inlet and outlet of each hydronic boiler shall be the following:
 - 1. Sealed, bimetallic-actuated type.
- B. Thermometers at inlets and outlets of each chiller shall be the following:
 - 1. Sealed, bimetallic-actuated type.
- C. Thermometers at inlet and outlet of each hydronic coil in air-handling units and built-up central systems shall be the following:
 - 1. Sealed, bimetallic-actuated type.
- D. Thermometers at inlet and outlet of each hydronic heat-recovery unit shall be the following:
 - 1. Sealed, bimetallic-actuated type.
- E. Thermometer stems shall be of length to match thermowell insertion length.

3.5 THERMOMETER SCALE-RANGE SCHEDULE

- A. Scale Range for Chilled-Water Piping: 0 to 150 deg F.
- B. Scale Range for Heating, Hot-Water Piping: 0 to 250 deg F.

3.6 PRESSURE-GAGE SCHEDULE

- A. Pressure gages at inlet and outlet of each chiller chilled-water and condenser-water connection shall be the following:
 - 1. Liquid-filled , direct -mounted, metal case.
- B. Pressure gages at suction and discharge of each pump shall be the following:
 - 1. Liquid-filled , direct -mounted, metal case.

3.7 PRESSURE-GAGE SCALE-RANGE SCHEDULE

- A. Scale Range for Chilled-Water Piping: 0 to 100 psi.
- B. Scale Range for Heating, Hot-Water Piping: 0 to 100 psi.

3.8 FLOWMETER SCHEDULE

- A. Flowmeters for Chilled-Water Piping: Venturi type.
- B. Flowmeters for Heating, Hot-Water Piping: Venturi type.

END OF SECTION 230519

SECTION 230523.12 - BALL VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Bronze ball valves.

1.3 DEFINITIONS

- A. CWP: Cold working pressure.
- B. SWP: Steam working pressure.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Prepare valves for shipping as follows:
 - 1. Protect internal parts against rust and corrosion.
 - 2. Protect threads, flange faces, and weld ends.
 - 3. Set ball valves open to minimize exposure of functional surfaces.
- B. Use the following precautions during storage:
 - 1. Maintain valve end protection.
 - 2. Store valves indoors and maintain at higher-than-ambient-dew-point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
- C. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use operating handles or stems as lifting or rigging points.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

- A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.
- B. ASME Compliance:
 - 1. ASME B1.20.1 for threads for threaded-end valves.
 - 2. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 - 3. ASME B31.1 for power piping valves.
 - 4. ASME B31.9 for building services piping valves.
- C. Bronze valves shall be made with dezincification-resistant materials. Bronze valves made with copper alloy (brass) containing more than 15 percent zinc are not permitted.
- D. Refer to HVAC valve schedule articles for applications of valves.
- E. Valve Pressure-Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- F. Valve Sizes: Same as upstream piping unless otherwise indicated.
- G. Valve Actuator Types:
 - 1. Gear Actuator: For quarter-turn valves NPS 4 and larger.
 - 2. Handlever: For quarter-turn valves smaller than NPS 4.
- H. Valves in Insulated Piping:
 - 1. Include 2-inch stem extensions.
 - 2. Extended operating handle of nonthermal-conductive material, and protective sleeves that allow operation of valves without breaking the vapor seals or disturbing insulation.
 - 3. Memory stops that are fully adjustable after insulation is applied.
- I. Valve Bypass and Drain Connections: MSS SP-45.

2.2 BRONZE BALL VALVES

- A. Bronze Ball Valves, Two-Piece with Full Port and Stainless-Steel Trim:
 - 1. Description:
 - a. Standard: MSS SP-110.
 - b. SWP Rating: 150 psig.
 - c. CWP Rating: 600 psig.
 - d. Body Design: Two piece.
 - e. Body Material: Bronze.
 - f. Ends: Threaded.
 - g. Seats: PTFE.
 - h. Stem: Stainless steel.
 - i. Ball: Stainless steel, vented.
 - j. Port: Full.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine threads on valve and mating pipe for form and cleanliness.
- D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- E. Do not attempt to repair defective valves; replace with new valves.

3.2 VALVE INSTALLATION

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Locate valves for easy access and provide separate support where necessary.
- C. Install valves in horizontal piping with stem at or above center of pipe.
- D. Install valves in position to allow full stem movement.
- E. Install valve tags. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for valve tags and schedules.

3.3 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

- A. If valves with specified SWP classes or CWP ratings are unavailable, the same types of valves with higher SWP classes or CWP ratings may be substituted.
- B. Select valves with the following end connections:
 - 1. For Copper Tubing, NPS 2 and Smaller: Threaded ends.
 - 2. For Steel Piping, NPS 2 and Smaller: Threaded ends.

3.4 CHILLED-WATER VALVE SCHEDULE

- A. Pipe NPS 2 and Smaller: bronze ball valves, two piece, with brass stainless-steel trim, full port, threaded - joint ends.

3.5 HEATING-WATER VALVE SCHEDULE

- A. Pipe NPS 2 and Smaller: bronze ball valves, two piece with stainless-steel trim, full port, threaded -joint ends.

END OF SECTION 230523.12

SECTION 230523.13 - BUTTERFLY VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Iron, single-flange butterfly valves.

1.3 DEFINITIONS

- A. CWP: Cold working pressure.
- B. EPDM: Ethylene propylene copolymer rubber.
- C. NBR: Acrylonitrile-butadiene, Buna-N, or nitrile rubber.
- D. SWP: Steam working pressure.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Prepare valves for shipping as follows:
 - 1. Protect internal parts against rust and corrosion.
 - 2. Protect threads, flange faces, grooves, and weld ends.
 - 3. Set butterfly valves closed or slightly open.
- B. Use the following precautions during storage:
 - 1. Maintain valve end protection.
 - 2. Store valves indoors and maintain at higher-than-ambient-dew-point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
- C. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

- A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.
- B. ASME Compliance:
 - 1. ASME B16.1 for flanges on iron valves.
 - 2. ASME B16.5 for pipe flanges and flanged fittings, NPS 1/2 through NPS 24.
 - 3. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 - 4. ASME B31.1 for power piping valves.
 - 5. ASME B31.9 for building services piping valves.
- C. AWWA Compliance: Comply with AWWA C606 for grooved-end connections.
- D. Valve Pressure-Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- E. Valve Sizes: Same as upstream piping unless otherwise indicated.
- F. Valve Actuator Types:
 - 1. Gear Actuator: For valves NPS 8 and larger.
 - 2. Handlever: For valves NPS 6 and smaller.
- G. Valves in Insulated Piping: With 2-inch stem extensions with extended necks.

2.2 IRON, SINGLE-FLANGE BUTTERFLY VALVES

- A. Iron, Single-Flange Butterfly Valves with Stainless-Steel Disc:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Apollo Valves; a part of Aalberts Integrated Piping Systems.
 - b. Bray International, Inc.
 - c. Crane.
 - d. Keystone.
 - e. KITZ Corporation.
 - f. Milwaukee Valve Company.
 - g. NIBCO INC.
 - h. Stockham; a Crane Co. brand.
 - 2. Description:
 - a. Standard: MSS SP-67, Type I.
 - b. CWP Rating: 200 psig.
 - c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
 - d. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
 - e. Seat: EPDM.
 - f. Stem: One- or two-piece stainless steel.
 - g. Disc: Stainless steel.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine mating flange faces for damage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- D. Do not attempt to repair defective valves; replace with new valves.

3.2 VALVE INSTALLATION

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Locate valves for easy access and provide separate support where necessary.
- C. Install valves in horizontal piping with stem at or above center of pipe.
- D. Install valves in position to allow full stem movement.
- E. Install valve tags. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for valve tags and schedules.

3.3 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.4 CHILLED-WATER VALVE SCHEDULE

- A. Pipe NPS 2-1/2 and Larger:
 - 1. Iron, Single-Flange Butterfly Valves, NPS 2-1/2 to NPS 12: Stainless-steel disc, 200 CWP, and EPDM seat.

3.5 HEATING-WATER VALVE SCHEDULE

- A. Pipe NPS 2-1/2 and Larger:
 - 1. Iron, Single-Flange Butterfly Valves, NPS 2-1/2 to NPS 12: Stainless-steel disc, 200 CWP, and EPDM seat.

END OF SECTION 230523.13

SECTION 230523.14 - CHECK VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Bronze swing check valves.
 - 2. Iron swing check valves.

1.3 DEFINITIONS

- A. CWP: Cold working pressure.
- B. EPDM: Ethylene propylene copolymer rubber.
- C. NBR: Acrylonitrile-butadiene, Buna-N, or nitrile rubber.
- D. SWP: Steam working pressure.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Prepare valves for shipping as follows:
 - 1. Protect internal parts against rust and corrosion.
 - 2. Protect threads, flange faces, grooves, and weld ends.
 - 3. Block check valves in either closed or open position.
- B. Use the following precautions during storage:
 - 1. Maintain valve end protection.
 - 2. Store valves indoors and maintain at higher than ambient dew point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
- C. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

- A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.
- B. ASME Compliance:
 - 1. ASME B1.20.1 for threads for threaded-end valves.
 - 2. ASME B16.1 for flanges on iron valves.
 - 3. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 - 4. ASME B16.18 for solder joint.
 - 5. ASME B31.1 for power piping valves.
 - 6. ASME B31.9 for building services piping valves.
- C. AWWA Compliance: Comply with AWWA C606 for grooved-end connections.
- D. Bronze valves shall be made with dezincification-resistant materials. Bronze valves made with copper alloy (brass) containing more than 15 percent zinc are not permitted.
- E. Valve Pressure-Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.
- F. Valve Sizes: Same as upstream piping unless otherwise indicated.
- G. Valve Bypass and Drain Connections: MSS SP-45.

2.2 BRONZE SWING CHECK VALVES

- A. Bronze Swing Check Valves with Bronze Disc, Class 150:
 - 1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Apollo Valves; a part of Aalberts Integrated Piping Systems.
 - b. Crane Fluid Systems; Crane Co.
 - c. Hammond Valve.
 - d. Jenkins Valves; a Crane Co. brand.
 - e. Milwaukee Valve Company.
 - f. NIBCO INC.
 - g. Stockham; a Crane Co. brand.
 - 2. Description:
 - a. Standard: MSS SP-80, Type 3.
 - b. CWP Rating: 300 psig.
 - c. Body Design: Horizontal flow.
 - d. Body Material: ASTM B 62, bronze.
 - e. Ends: Threaded.
 - f. Disc: Bronze.

B. Bronze Swing Check Valves with Nonmetallic Disc, Class 150:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Crane Fluid Systems; Crane Co.
 - b. Jenkins Valves; a Crane Co. brand.
 - c. Milwaukee Valve Company.
 - d. NIBCO INC.
 - e. Stockham; a Crane Co. brand.
2. Description:
 - a. Standard: MSS SP-80, Type 4.
 - b. CWP Rating: 300 psig.
 - c. Body Design: Horizontal flow.
 - d. Body Material: ASTM B 62, bronze.
 - e. Ends: Threaded.
 - f. Disc: PTFE.

2.3 IRON SWING CHECK VALVES

A. Iron Swing Check Valves with Metal Seats, Class 250:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Apollo Valves; a part of Aalberts Integrated Piping Systems.
 - b. Crane Fluid Systems; Crane Co.
 - c. DeZURIK.
 - d. Hammond Valve.
 - e. Jenkins Valves; a Crane Co. brand.
 - f. Milwaukee Valve Company.
 - g. Victaulic Company.
2. Description:
 - a. Standard: MSS SP-71, Type I.
 - b. NPS 2-1/2 to NPS 12, CWP Rating: 500 psig.
 - c. NPS 14 to NPS 24, CWP Rating: 300 psig.
 - d. Body Design: Clear or full waterway.
 - e. Body Material: ASTM A 126, gray iron with bolted bonnet.
 - f. Ends: Flanged.
 - g. Trim: Bronze.
 - h. Gasket: Asbestos free.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.

- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine threads on valve and mating pipe for form and cleanliness.
- D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- E. Do not attempt to repair defective valves; replace with new valves.

3.2 VALVE INSTALLATION

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Locate valves for easy access and provide separate support where necessary.
- C. Install valves in horizontal piping with stem at or above center of pipe.
- D. Install valves in position to allow full stem movement.
- E. Install check valves for proper direction of flow and as follows:
 - 1. Swing Check Valves: In horizontal position with hinge pin level.
- F. Install valve tags. Comply with requirements for valve tags and schedules in Section 230553 "Identification for HVAC Piping and Equipment."

3.3 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.4 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

- A. If valves with specified SWP classes or CWP ratings are unavailable, the same types of valves with higher SWP classes or CWP ratings may be substituted.
- B. Select valves, except wafer types, with the following end connections:
 - 1. For Copper Tubing, NPS 2 and Smaller: Threaded ends except where solder-joint valve-end option is indicated in valve schedules.
 - 2. For Copper Tubing, NPS 2-1/2 to NPS 4: Flanged ends except where threaded valve-end option is indicated in valve schedules.
 - 3. For Copper Tubing, NPS 5 and Larger: Flanged ends.
 - 4. For Steel Piping, NPS 2 and Smaller: Threaded ends.
 - 5. For Steel Piping, NPS 2-1/2 to NPS 4: Flanged ends except where threaded valve-end option is indicated in valve schedules.
 - 6. For Steel Piping, NPS 5 and Larger: Flanged ends.

3.5 CHILLED-WATER VALVE SCHEDULE

A. Pipe NPS 2 and Smaller:

1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
2. Bronze swing check valves with bronze disc, Class 250.

B. Pipe NPS 2-1/2 and Larger:

1. NPS 2-1/2 to NPS 4: Iron valves may be provided with threaded ends instead of flanged ends.
2. Iron swing check valves with metal seats, Class 250.

3.6 HEATING-WATER VALVE SCHEDULE

A. Pipe NPS 2 and Smaller:

1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
2. Bronze swing check valves with bronze disc, Class 250.

B. Pipe NPS 2-1/2 to NPS 8:

1. NPS 2-1/2 to NPS 4: Iron valves may be provided with threaded ends instead of flanged ends.
2. Iron swing check valves with meal seats, Class 250.

END OF SECTION 230523.14

SECTION 230529 - HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Metal pipe hangers and supports.
2. Trapeze pipe hangers.
3. Thermal-hanger shield inserts.
4. Fastener systems.
5. Pipe stands.
6. Equipment stands.
7. Equipment supports.

B. Related Requirements:

1. Section 055000 "Metal Fabrications" for structural-steel shapes and plates for trapeze hangers for pipe and equipment supports.
2. Section 230516 "Expansion Fittings and Loops for HVAC Piping" for pipe guides and anchors.
3. Section 230548 "Vibration and Seismic Controls for HVAC" Section 230548.13 "Vibration Controls for HVAC" for vibration isolation devices.
4. Section 233113 "Metal Ducts" for duct hangers and supports.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Structural Performance: Hangers and supports for HVAC piping and equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7.

1. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.
2. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.
3. Design seismic-restraint hangers and supports for piping and equipment and obtain approval from authorities having jurisdiction.

2.2 METAL PIPE HANGERS AND SUPPORTS

A. Carbon-Steel Pipe Hangers and Supports:

1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
2. Galvanized Metallic Coatings: Pregalvanized, hot-dip galvanized, or electro-galvanized.
3. Nonmetallic Coatings: Plastic coated, or epoxy powder-coated.
4. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
5. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel.

2.3 TRAPEZE PIPE HANGERS

- A. Description: MSS SP-58, Type 59, shop- or field-fabricated pipe-support assembly made from structural carbon-steel shapes with MSS SP-58 carbon-steel hanger rods, nuts, saddles, and U-bolts.

2.4 THERMAL-HANGER SHIELD INSERTS

- A. Insulation-Insert Material for Cold Piping: ASTM C552, Type II cellular glass with 100-psi or ASTM C591, Type VI, Grade 1 polyisocyanurate with 125-psi minimum compressive strength and vapor barrier.
- B. Insulation-Insert Material for Hot Piping: ASTM C552, Type II cellular glass with 100-psi or ASTM C591, Type VI, Grade 1 polyisocyanurate with 125-psi minimum compressive strength.
- C. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.
- D. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.
- E. Insert Length: Extend 2 inches beyond sheet metal shield for piping operating below ambient air temperature.

2.5 FASTENER SYSTEMS

- A. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Hilti, Inc.
 - b. ITW Ramset/Red Head; Illinois Tool Works, Inc.
 - c. Rawl.
- B. Mechanical-Expansion Anchors: Insert-wedge-type anchors for use in hardened portland cement concrete; with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Hilti, Inc.
 - b. ITW Ramset/Red Head; Illinois Tool Works, Inc.
 - 2. Indoor Applications: Zinc-coated or stainless steel.
 - 3. Outdoor Applications: Stainless steel.

2.6 PIPE STANDS

- A. General Requirements for Pipe Stands: Shop- or field-fabricated assemblies made of manufactured corrosion-resistant components to support roof-mounted piping.

B. Compact Pipe Stand:

1. Description: Single base unit with integral-rod roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.
2. Base: Single, vulcanized rubber, molded polypropylene, or polycarbonate.
3. Hardware: Galvanized steel or polycarbonate.
4. Accessories: Protection pads.

C. Curb-Mounted-Type Pipe Stands: Shop- or field-fabricated pipe supports made from structural-steel shapes, continuous-thread rods, and rollers, for mounting on permanent stationary roof curb.

2.7 EQUIPMENT SUPPORTS

- A. Description: Welded, shop- or field-fabricated equipment support made from structural carbon-steel shapes.

2.8 OUTDOOR EQUIPMENT STANDS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. MIRO Industries.
2. RectorSeal HVAC; a CSW Industrials Company.

2.9 MATERIALS

- A. Aluminum: ASTM B221.
- B. Carbon Steel: ASTM A1011/A1011M.
- C. Structural Steel: ASTM A36/A36M, carbon-steel plates, shapes, and bars; galvanized.
- D. Stainless Steel: ASTM A240/A240M.
- E. Threaded Rods: Continuously threaded. Zinc-plated or galvanized steel for indoor applications and stainless steel for outdoor applications. Mating nuts and washers of similar materials as rods.
- F. Grout: ASTM C1107/C1107M, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.
1. Properties: Nonstaining, noncorrosive, and nongaseous.
 2. Design Mix: 5000-psi, 28-day compressive strength.

PART 3 - EXECUTION

3.1 APPLICATION

- A. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping materials and installation for penetrations through fire-rated walls, ceilings, and assemblies.

- B. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lb.

3.2 HANGER AND SUPPORT INSTALLATION

- A. Metal Pipe-Hanger Installation: Comply with MSS SP-58. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.
- B. Metal Trapeze Pipe-Hanger Installation: Comply with MSS SP-58. Arrange for grouping of parallel runs of horizontal piping, and support together on field-fabricated trapeze pipe hangers.
 - 1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified for individual pipe hangers.
 - 2. Field fabricate from ASTM A36/A36M, carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.
- C. Fiberglass Pipe-Hanger Installation: Comply with applicable portions of MSS SP-58. Install hangers and attachments as required to properly support piping from building structure.
- D. Metal Framing System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled strut systems.
- E. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.
- F. Fastener System Installation:
 - 1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.
 - 2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.
- G. Pipe Stand Installation:
 - 1. Pipe Stand Types except Curb-Mounted Type: Assemble components and mount on smooth roof surface. Do not penetrate roof membrane.
 - 2. Curb-Mounted-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. See Section 077200 "Roof Accessories" for curbs.
- H. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.
- I. Equipment Support Installation: Fabricate from welded-structural-steel shapes.
- J. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.
- K. Install lateral bracing with pipe hangers and supports to prevent swaying.
- L. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 and larger and at changes in

direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

- M. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.
- N. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.
- O. Insulated Piping:
 - 1. Attach clamps and spacers to piping.
 - a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
 - b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
 - c. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.
 - 2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
 - a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
 - 3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.
 - a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
 - 4. Shield Dimensions for Pipe: Not less than the following:
 - a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick.
 - b. NPS 4: 12 inches long and 0.06 inch thick.
 - c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick.
 - d. NPS 8 to NPS 14: 24 inches long and 0.075 inch thick.
 - e. NPS 16 to NPS 24: 24 inches long and 0.105 inch thick.
 - 5. Pipes NPS 8 and Larger: Include cellular glass or reinforced calcium-silicate-insulation inserts of length at least as long as protective shield.
 - 6. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

3.3 EQUIPMENT SUPPORTS

- A. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.
- B. Grouting: Place grout under supports for equipment and make bearing surface smooth.
- C. Provide lateral bracing, to prevent swaying, for equipment supports.

3.4 METAL FABRICATIONS

- A. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.
- B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.
- C. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:
 - 1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
 - 2. Obtain fusion without undercut or overlap.
 - 3. Remove welding flux immediately.
 - 4. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

3.5 ADJUSTING

- A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.
- B. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches.

3.6 PAINTING

- A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.
 - 1. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils.
- B. Touchup: Comply with requirements Section 099113 "Exterior Painting" Section 099123 "Interior Painting" and Section 099600 "High-Performance Coatings" for cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal.
- C. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A780/A780M.

3.7 HANGER AND SUPPORT SCHEDULE

- A. Specific hanger and support requirements are in Sections specifying piping systems and equipment.
- B. Comply with MSS SP-58 for pipe-hanger selections and applications that are not specified in piping system Sections.
- C. Use hangers and supports with galvanized metallic coatings for piping and equipment that will not have field-applied finish.
- D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

- E. Use carbon-steel pipe hangers and supports and attachments for general service applications.
- F. Use padded hangers for piping that is subject to scratching.
- G. Use thermal-hanger shield inserts for insulated piping and tubing.
- H. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
 - 1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated, stationary pipes NPS 1/2 to NPS 30.
 - 2. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes NPS 3/4 to NPS 36, requiring clamp flexibility and up to 4 inches of insulation.
 - 3. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes NPS 1/2 to NPS 24 if little or no insulation is required.
 - 4. Pipe Hangers (MSS Type 5): For suspension of pipes NPS 1/2 to NPS 4, to allow off-center closure for hanger installation before pipe erection.
 - 5. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of noninsulated, stationary pipes NPS 1/2 to NPS 8.
 - 6. Extension Hinged or Two-Bolt Split Pipe Clamps (MSS Type 12): For suspension of noninsulated, stationary pipes NPS 3/8 to NPS 3.
 - 7. U-Bolts (MSS Type 24): For support of heavy pipes NPS 1/2 to NPS 30.
 - 8. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
 - 9. Pipe Stanchion Saddles (MSS Type 37): For support of pipes NPS 4 to NPS 36, with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate, and with U-bolt to retain pipe.
 - 10. Adjustable Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes NPS 2-1/2 to NPS 36 if vertical adjustment is required, with steel-pipe base stanchion support and cast-iron floor flange.
 - 11. Single-Pipe Rolls (MSS Type 41): For suspension of pipes NPS 1 to NPS 30, from two rods if longitudinal movement caused by expansion and contraction might occur.
 - 12. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes NPS 2-1/2 to NPS 24, from single rod if horizontal movement caused by expansion and contraction might occur.
 - 13. Complete Pipe Rolls (MSS Type 44): For support of pipes NPS 2 to NPS 42 if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is unnecessary.
 - 14. Pipe Roll and Plate Units (MSS Type 45): For support of pipes NPS 2 to NPS 24 if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is unnecessary.
 - 15. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes NPS 2 to NPS 30 if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.
- I. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
 - 1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers NPS 3/4 to NPS 24.
- J. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
 - 1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.
 - 2. Steel Clevises (MSS Type 14): For 120 to 450 deg F piping installations.
 - 3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
 - 4. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
 - 5. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F piping installations.

- K. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
 2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joist construction, to attach to top flange of structural shape.
 3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
 4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
 5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
 6. C-Clamps (MSS Type 23): For structural shapes.
 7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
 8. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
 9. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
 10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
 11. Malleable-Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
 12. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:
 - a. Light (MSS Type 31): 750 lb.
 - b. Medium (MSS Type 32): 1500 lb.
 - c. Heavy (MSS Type 33): 3000 lb.
 13. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
 14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
 15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.
- L. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel-Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
 2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
 3. Thermal-Hanger Shield Inserts: For supporting insulated pipe.
- M. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections or Sections 230548 "Vibration and Seismic Control for HVAC" or 230548.13 "Vibration Control for HVAC", install the following types:
1. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.
- N. Comply with MSS SP-58 for trapeze pipe-hanger selections and applications that are not specified in piping system Sections.
- O. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.

- P. Use powder-actuated fasteners or mechanical-expansion anchors instead of building attachments where required in concrete construction.

END OF SECTION 230529

SECTION 230533 - HEAT TRACING FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes heat tracing for HVAC piping with the following electric heating cables:
 - 1. Self-regulating, parallel resistance.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, and furnished specialties and accessories.
 - 2. Schedule heating capacity, length of cable, spacing, and electrical power requirement for each electric heating cable required.

1.4 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace electric heating cable that fails in materials or workmanship within specified warranty period.
 - 1. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 SELF-REGULATING, PARALLEL-RESISTANCE HEATING CABLES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Chromalox, Inc.
 - 2. RAYCHEM; brand of nVent Electrical plc.
- B. Comply with IEEE 515.1.
- C. Heating Element: Pair of parallel No. 16 AWG, nickel-coated, stranded copper bus wires embedded in crosslinked conductive polymer core, which varies heat output in response to temperature along its length. Terminate with waterproof, factory-assembled, nonheating leads with connectors at one end, and seal the opposite end watertight. Cable shall be capable of crossing over itself once without overheating.
- D. Electrical Insulating Jacket: Flame-retardant polyolefin.

- E. Cable Cover: Stainless-steel braid and polyolefin outer jacket with ultraviolet inhibitor.
- F. Maximum Operating Temperature (Power On): 150 deg F.
- G. Maximum Exposure Temperature (Power Off): 185 deg F.
- H. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 CONTROLS

- A. Remote bulb unit with adjustable temperature range from 30 to 50 deg F.
- B. Snap action; open-on-rise, single-pole switch with minimum current rating adequate for connected cable.
- C. Remote bulb on capillary, resistance temperature device, or thermistor for directly sensing pipe-wall temperature.
- D. Corrosion-resistant, waterproof control enclosure.

2.3 ACCESSORIES

- A. Cable Installation Accessories: Fiberglass tape, heat-conductive putty, cable ties, silicone end seals and splice kits, and installation clips all furnished by manufacturer, or as recommended in writing by manufacturer.
- B. Warning Labels: Refer to Section 230553 "Identification for HVAC Piping and Equipment."
- C. Warning Tape: Continuously printed "Electrical Tracing"; vinyl, at least 3 mils thick, and with pressure-sensitive, permanent, waterproof, self-adhesive back.
 - 1. Width for Markers on Pipes with OD, Including Insulation, Less Than 6 Inches: 3/4 inch minimum.
 - 2. Width for Markers on Pipes with OD, Including Insulation, 6 Inches or Larger: 1-1/2 inches minimum.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine surfaces and substrates to receive electric heating cables for compliance with requirements for installation tolerances and other conditions affecting performance.
 - 1. Ensure surfaces and pipes in contact with electric heating cables are free of burrs and sharp protrusions.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install electric heating cable across expansion joints according to manufacturer's written instructions; use slack cable to allow movement without damage to cable.
- B. Install electric heating cables after piping has been tested and before insulation is installed.
- C. Install electric heating cables according to IEEE 515.1.
- D. Install insulation over piping with electric cables according to Section 230719 "HVAC Piping Insulation."
- E. Install warning tape on piping insulation where piping is equipped with electric heating cables.
- F. Set field-adjustable switches and circuit-breaker trip ranges.

3.3 CONNECTIONS

- A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
 - 1. Perform tests after cable installation but before application of coverings such as insulation, wall or ceiling construction, or concrete.
 - 2. Test cables for electrical continuity and insulation integrity before energizing.
 - 3. Test cables to verify rating and power input. Energize and measure voltage and current simultaneously.
- C. Repeat tests for continuity, insulation resistance, and input power after applying thermal insulation on pipe-mounted cables.
- D. Cables will be considered defective if they do not pass tests and inspections.
- E. Prepare test and inspection reports.

3.5 PROTECTION

- A. Protect installed heating cables, including nonheating leads, from damage during construction.
- B. Remove and replace damaged heat-tracing cables.

END OF SECTION 230533

SECTION 230546 - COATINGS FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. General provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes application of coating systems on internal HVAC components and external equipment surfaces, including the following systems:
 - 1. Air-dried corrosion-resistant coating systems.

1.3 DEFINITIONS

- A. Salt Water Acetic Acid Test (SWAAT): A salt fog-spray test of corrosion resistance performed in accordance with ASTM G85, Annex 3.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include Safety Data Sheets, preparation requirements, and application instructions.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Store materials not in use in tightly covered containers in clean, dry, well-ventilated areas with ambient temperatures continuously maintained between 50 and 75 deg F.
 - 1. Keep containers out of direct sunlight; avoid excessive heat and keep from freezing.
 - 2. Maintain containers in clean condition, free of foreign materials and residue.
 - 3. Remove rags and waste from storage areas daily.

1.6 CONDITIONS FOR COATING APPLICATION

- A. Comply with manufacturer's recommendations regarding required temperature and humidity ranges during coating application.

PART 2 - PRODUCTS

2.1 CORROSION-RESISTANT COATING SYSTEMS, GENERAL

A. Material Compatibility:

1. Provide materials for application within each coating system that are compatible with one another and with metal substrates indicated, under conditions of service and application as demonstrated by manufacturer, based on testing and field experience.
2. For each coating material in coating system, submit compatibility certification from manufacturer of each coating product that products are compatible with substrate base material and with substrate-coating products applied as earlier coats.
3. Products shall be of same manufacturer for each coat in a coating system.

B. Colors: Manufacturer's standard.

2.2 AIR-DRIED CORROSION-RESISTANT COATING SYSTEMS

A. Performance Requirements:

1. Corrosion Resistance: ASTM B117: 2000 hours.

B. Air-Dried, Spray-Applied Coating System.

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Modine Manufacturing Company.

C. Base Coat Performance Requirements:

1. Corrosion Resistance: ASTM B117: 2000 hours.

D. Air-Dried Top Coat Performance Requirements: Provide product with UV shielding properties, color stability, and maintenance of manufacturer's standard sheen, after exposure to outdoor conditions.

E. Spray-Can Application Systems:

1. Type: Air dry, phenolic.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Applicator present, for compliance with coating manufacturer's requirements and other conditions affecting performance of the Work.
- B. Verify suitability of substrates, including surface conditions and compatibility, with existing finishes and primers.

- C. Proceed with coating application only after unsatisfactory conditions have been corrected.

- 1. Application of coating indicates acceptance of surfaces and conditions.

3.2 PREPARATION

- A. Comply with manufacturer's written instructions applicable to substrates and coating systems indicated.

- 1. Thinning: Thin coating material with manufacturer's recommended thinning products when recommended or permitted by coating system manufacturer.

- B. Comply with coating system manufacturer's recommendations to clean substrates of substances that could impair bond of coatings, including dust, dirt, oil, grease, and incompatible paints and encapsulants.

3.3 APPLICATION

- A. Verify with coating manufacturer whether coatings required must be applied and cured in factory-certified application shop.

- B. Apply coating systems with equipment designed to deposit coating of specified uniform thickness over HVAC components, in complex, three-dimensional geometries.

- 1. Apply coatings with manufacturer-recommended tools and techniques suited for specified coating system and each coated HVAC component.
 - 2. Do not apply coatings over labels or equipment name, identification, performance rating, or nomenclature plates.

- C. Perform inspection and coating system manufacturer's recommended tests to verify coating integrity and thickness. Where coating was damaged by testing, repair damage in accordance with coating system manufacturer's written recommendations.

END OF SECTION 230546

SECTION 230548.13 - VIBRATION CONTROLS FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Elastomeric isolation pads.
2. Elastomeric isolation mounts.
3. Neoprene Isolation Washers and Grommets
4. Open-spring isolators.
5. Restrained-spring isolators.
6. Pipe-riser resilient support.
7. Resilient pipe guides.
8. Elastomeric hangers.
9. Spring hangers.
10. Precompressed Spring Hangers
11. Manufactured Pipe Isolation Hangers
12. Field Assembled Pipe Isolation Hangers
13. Snubbers.
14. Restraints - rigid type.
15. Restraints - cable type.
16. Restraint accessories.
17. Post-installed concrete anchors.
18. Concrete inserts.
19. Vibration isolation equipment bases.
20. Restrained isolation roof-curb rails.
21. Elastomeric Curb Isolation
22. Flexible Connections
23. Thrust Restraints

B. Related Requirements:

1. Section 210548.13 "Vibration Controls for Fire-Suppression Piping and Equipment" for devices for fire-suppression equipment and systems.
2. Section 220548.13 "Vibration Controls for Plumbing Piping and Equipment" for devices for plumbing equipment and systems.

1.3 DEFINITIONS

- A. IBC: International Building Code.
- B. OSHPD: Office of Statewide Health Planning and Development (for the State of California owned and regulated medical facilities).

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include vibration isolation mounts and hangers, including isolator data, isolated equipment operating weight, actual load distribution and actual static deflection at each loading point for each piece of isolated equipment.
2. Include equipment base and isolation curb drawings and details including dimensions and materials.
3. Include flexible duct and pipe connector data sheets including manufacturer's ratings for pressure and temperature.
4. Include load rating for each wind-force-restraint fitting and assembly.
5. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of vibration isolation device and wind-force-restraint component.
6. Annotate to indicate application of each product submitted and compliance with requirements.
7. Interlocking Snubbers: Include ratings for horizontal, vertical, and combined loads.

B. Shop Drawings:

1. Detail fabrication and assembly of equipment bases.
2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
3. Shop drawings for piping isolators shall be made on prints of the piping shop drawings.

C. Delegated-Design Submittal:

1. For each wind-load protection device that is required by this Section or is indicated on Drawings, submit the following:
 - a. Vibration Isolator and Wind-Load-Restraint Selection: Select vibration isolators, wind-load restraints, and vibration isolation bases complying with performance requirements, design criteria, and analysis data.
 - b. Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure, and spring deflection changes. Include certification by professional engineer that riser system was examined for excessive stress and that none exists.
 - c. Concrete Anchors and Inserts: Include calculations showing anticipated wind loads.
 - d. Wind-Load Design Calculations: Submit all static and dynamic loading calculations prepared under "Wind-Load Design Calculations" Paragraph in "Performance Requirements" Article.
 - e. Qualified Professional Engineer: All designated-design submittals for wind-restraint calculations are to be signed and sealed by qualified professional engineer responsible for their preparation.
2. Wind-Restraint Detail Drawing:
 - a. Design Analysis: To support selection and arrangement of wind restraints. Include calculations of combined tensile and shear loads.
 - b. Details: Indicate fabrication and arrangement. Detail attachments of restraints to restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during wind events. Indicate association with vibration isolation devices.
 - c. Coordinate vibration isolation details with wind-restraint details required for equipment mounted outdoors. Comply also with requirements in other Sections for equipment mounted outdoors.

3. All delegated-design submittals for wind-restraint detail Drawings are to be signed and sealed by qualified professional engineer responsible for their preparation.
4. Product Listing, Preapproval, and Evaluation Documentation: By an agency acceptable to authorities having jurisdiction, showing maximum ratings of restraint items and basis for approval (tests or calculations).
5. Design Calculations for Vibration Isolation Devices: Calculate static and dynamic loading due to equipment weight and operating forces required to select proper vibration isolators, and to design vibration isolation bases.
6. Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure, and spring deflection changes. Include certification that riser system was examined for excessive stress and that none exists.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Show coordination of vibration isolation device installation for HVAC piping and equipment with other systems and equipment in the vicinity, including other supports and restraints.
- B. Qualification Data: For testing agency.
- C. Welding certificates.
- D. Field quality-control reports.
- E. Wind-Force Performance Certification: Provide special certification for HVAC components subject to high wind exposure and impact damage and designated on Drawings or in the Specifications to require wind-force performance certification.
 1. Provide equipment manufacturer's written certification for each designated HVAC device, stating that it will remain in place and operable following the design wind event and comply with all requirements of authorities having jurisdiction.
 2. Provide manufacturer's written certification for each designated louver, damper, or similar device, stating that it will remain in place and protect opening from penetration of windborne debris and comply with all requirements of authorities having jurisdiction.
 3. Certification must be based on ICC-ES or similar nationally recognized testing standard procedures acceptable to authorities having jurisdiction.

1.6 QUALITY ASSURANCE

- A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct testing indicated, be an NRTL as defined by OSHA in 29 CFR 1910.7 and be acceptable to authorities having jurisdiction.
- B. Welding Qualifications: Qualify procedures and personnel in accordance with AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- C. Wind-Load-Restraint Device Load Ratings: Devices to be tested and rated in accordance with applicable code requirements and authorities having jurisdiction. Devices to be listed by a nationally recognized third party that requires periodic follow-up inspections and has a listing directory available to the public. Provide third-party listing by one or more of the following: an agency acceptable to authorities having jurisdiction.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design system.
- B. Wind-Load Design Calculations:
 - 1. Perform calculations to obtain force information necessary to properly select wind-load-restraint devices, fasteners, and anchorage. Perform calculations using methods acceptable to applicable code authorities and as presented in ASCE/SEI 7 edition or other wind-force calculation method required by authorities having jurisdiction. Where "ASCE/SEI 7" is used throughout this Section, it is to be understood that the edition referred to in this subparagraph is intended as referenced throughout the Section Text unless otherwise noted.
 - a. Factors indicated on the Drawing schedules that are specific to individual pieces of equipment must be obtained by Contractor and must be included in individual component submittal packages.
 - b. Coordinate design wind-load calculations with vibration isolation requirements. Comply with requirements in other Sections in addition to those in this Section for equipment mounted outdoors.
- C. Consequential Damage: Provide additional restraints for suspended HVAC components or anchorage of floor-, roof-, or wall-mounted HVAC components as indicated in ASCE/SEI 7-16 so that failure of a non-essential or essential HVAC component will not cause the failure of any other essential architectural, mechanical, or electrical building component.
- D. Fire/Smoke Resistance: All components that are not constructed of ferrous metals must have a maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested by an NRTL in accordance with ASTM E84 or UL 723, and be so labeled.
- E. Component Supports:
 - 1. Load ratings, features, and applications of all reinforcement components must be based on testing standards of a nationally recognized testing agency.

2.2 ELASTOMERIC ISOLATION PADS

- A. Elastomeric Isolation Pads: NP.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - e. Vibro-Acoustics.
 - 2. Fabrication: Single or multiple layers of sufficient durometer stiffness for uniform loading over pad area.
 - 3. Size: Factory or field cut to match requirements of supported equipment.

4. Pad Material: Oil- and water-resistant rubber. Neoprene rubber, silicone rubber, or other elastomeric material.
5. Ribbed or waffled on both sides.
6. Minimum thickness 0.75".
7. Load-bearing metal plates adhered to pads as recommended by isolation pad manufacturer for loading conditions.

2.3 ELASTOMERIC ISOLATION MOUNTS

A. Elastomeric Isolation Mounts: DN.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - e. Vibro-Acoustics.
2. Mounting Plates:
 - a. Top Plate: Encapsulated steel load transfer top plates, factory drilled and threaded with threaded studs or bolts.
 - b. Baseplate: Encapsulated steel bottom plates with holes provided for anchoring to support structure.
3. Elastomeric Material: Molded, oil-resistant rubber, neoprene, or other elastomeric material.

2.4 NEOPRENE ISOLATION WASHERS AND GROMMETS

A. Neoprene Isolation Washer and Grommets: IWG.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - e. Vibro-Acoustics.
2. Neoprene isolation washer and grommets shall have a nominal durometer of Shore 50A.

2.5 OPEN-SPRING ISOLATORS

A. Freestanding, Laterally Stable, Open-Spring Isolators: FS.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.

e. Vibro-Acoustics.

2. Unhoused combination spring with neoprene type.
3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
7. Baseplate shall limit floor load to 500 psig.
8. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

2.6 RESTRAINED-SPRING ISOLATORS

A. Freestanding, Laterally Stable, Open-Spring Isolators with Vertical-Limit Stop Restraint: LS.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - e. Vibro-Acoustics.
2. Housing: Steel housing with vertical-limit stops to prevent spring extension due to weight being removed.
 - a. Base shall limit floor load to 500 psig.
 - b. Top plate with threaded mounting holes.
 - c. Internal leveling bolt that acts as blocking during installation.
3. Combination spring and neoprene type.
4. Restraint: Limit stop as required for equipment and authorities having jurisdiction.
 - a. Limit stops shall be out of contact with the housing during normal operation.
5. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
6. Minimum Additional Travel: 50 percent of the required deflection at rated load.
7. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
8. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

2.7 PIPE-RISER RESILIENT SUPPORT

A. All-Directional, Acoustical Pipe Anchor Consisting of Two Steel Tubes Separated by a Minimum 1/2-inch-Thick Neoprene: NA.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.

- b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mounting & Controls, Inc.
- 2. Vertical-Limit Stops: Steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions.
 - 3. Maximum Load Per Support: 500 psi on isolation material providing equal isolation in all directions.

2.8 RESILIENT PIPE GUIDES

- A. Telescopic Arrangement of Two Steel Tubes or Post and Sleeve Arrangement Separated by a Minimum 1/2-inch- Thick Neoprene: NR.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - 2. Factory-Set Height Guide with Shear Pin: Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

2.9 ELASTOMERIC HANGERS

- A. Elastomeric Mount in a Steel Frame with Upper and Lower Steel Hanger Rods: NH.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - e. Vibro-Acoustics.
 - 2. Frame: Steel, fabricated with a connection for an upper threaded hanger rod and an opening on the underside to allow for a maximum of 30 degrees of angular lower hanger-rod misalignment without binding or reducing isolation efficiency.
 - 3. Damping Element: Molded, oil-resistant rubber, neoprene, or other elastomeric material with a projecting bushing for the underside opening preventing steel-to-steel contact.

2.10 SPRING HANGERS

- A. Combination Coil-Spring and Elastomeric-Insert Hanger with Spring and Insert in Compression: SH.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - e. Vibro-Acoustics.

2. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.
3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
7. Elastomeric Element: Molded, oil-resistant rubber or neoprene. Steel-washer-reinforced cup to support spring and bushing projecting through bottom of frame.
8. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

2.11 PRECOMPRESSED SPRING HANGERS

- A. Precompressed Combination Coil-Spring and Elastomeric-Insert Hanger with Spring and Insert in Compression: PSH.
1. Shall meet all of the specified requirements of Type SH spring hangers.
 2. Shall be provided precompressed by the manufacturer to the rated deflection. Hanger shall have a release mechanical to free the spring after installation is complete.

2.12 MANUFACTURED PIPING ISOLATION HANGER

- A. Pipe Hanger Manufactured With Elastomeric Vibration Isolation Layer: PIM.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. HoldRite
 - b. Elmdor Stoneman
 - c. F&A Products, Inc.
 2. Elastomeric Layer: 30-50 durometer ribbed neoprene, thermoplastics rubber, or crumb rubber.
 3. Inside diameter sized for piping outside diameter.

2.13 FIELD ASSEMBLED PIPING ISOLATION HANGER

- A. Field Assembled Piping Isolation Hanger Treatment: PIF.
1. 1/2" thick closed cell elastomeric foam insulation layer installed between the pipe and hanger.
 2. Minimum 3" wide strip or as required to provide 1" overhang on each side of support pipe.
 3. Oversize pipe hangers by a minimum of 3/4" to prevent crushing of foam insulation.
 4. Multiple layers of closed cell insulation may be used to reach the required thickness.
 5. Closed cell foam insulation to be Armacell AP or Equal.

2.14 SNUBBERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Kinetics Noise Control, Inc.
 2. Mason Industries, Inc.
 3. Vibration Eliminator Co., Inc.

4. Vibration Mountings & Controls, Inc.
5. Vibro-Acoustics.

B. Description: Factory fabricated using welded structural-steel shapes and plates, anchor bolts, and replaceable resilient isolation washers and bushings.

1. Post-Installed Concrete Anchor Bolts: Secure to concrete surface with post-installed concrete anchors. Anchors to be prequalified in accordance with ACI 355.2 testing and designated in accordance with ACI 318-14 Ch. 17 for 2015 or 2018 IBC.
2. Preset Concrete Inserts: Prequalified in accordance with ICC-ES AC446 testing.
3. Anchors in Masonry: Design in accordance with TMS 402.
4. Resilient Isolation Washers and Bushings: Oil- and water-resistant neoprene.
5. Resilient Cushion: Maximum 1/4-inch air gap, and minimum 1/4 inch thick.

2.15 RESTRAINTS - RIGID TYPE

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. CADDY; nVent.
2. Gripple Inc.
3. International Seismic Application Technology (ISAT).
4. Kinetics Noise Control, Inc.
5. Mason Industries, Inc.
6. Vibration Eliminator Co., Inc.
7. Vibration Mountings & Controls, Inc.
8. Vibro-Acoustics.

B. Description: Shop- or field-fabricated bracing assembly made of AISI S110-07-S1 slotted steel channels, ANSI/ASTM A53/A53M steel pipe as per NFPA 13, or other rigid steel brace member. Includes accessories for attachment to braced component at one end and to building structure at the other end and other matching components and with corrosion-resistant coating; rated in tension, compression, and torsion forces.

2.16 RESTRAINTS - CABLE TYPE

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. CADDY; nVent.
2. Gripple Inc.
3. Kinetics Noise Control, Inc.
4. Mason Industries, Inc.
5. Vibration Eliminator Co., Inc.
6. Vibration Mountings & Controls, Inc.
7. Vibro-Acoustics.

B. Restraint Cables: ASTM A492 stainless steel cables. End connections made of steel assemblies with thimbles, brackets, swivel, and bolts designed for restraining cable service; with fittings attached by means of poured socket, swaged socket, or mechanical (Flemish eye) loop.

C. Restraint cable assembly and cable fittings must comply with ASCE/SEI 19-16. All cable fittings and complete cable assembly must maintain the minimum cable breaking force. U-shaped cable clips and wedge-type end fittings do not comply and are unacceptable.

2.17 RESTRAINT ACCESSORIES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. CADDY; nVent.
 2. Gripple Inc.
 3. International Seismic Application Technology (ISAT).
 4. Kinetics Noise Control, Inc.
 5. Mason Industries, Inc.
 6. Vibration Eliminator Co., Inc.
 7. Vibration Mounting & Controls, Inc.
 8. Vibro-Acoustics.
- B. Hanger-Rod Stiffener: Steel tube or steel slotted-support-system sleeve with internally bolted connections Reinforcing steel angle clamped to hanger rod.
- C. Hinged and Swivel Brace Attachments: Multifunctional steel connectors for attaching hangers to rigid channel bracings and] restraint cables.
- D. Bushings for Floor-Mounted Equipment Anchor Bolts: Neoprene bushings designed for rigid equipment mountings, and matched to type and size of anchor bolts and studs.
- E. Bushing Assemblies for Wall-Mounted Equipment Anchorage: Assemblies of neoprene elements and steel sleeves designed for rigid equipment mountings, and matched to type and size of attachment devices used.
- F. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.

2.18 POST-INSTALLED CONCRETE ANCHORS

- A. Mechanical Anchor Bolts:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. DeWALT.
 - b. Hilti, Inc.
 - c. Simpson Strong-Tie Co., Inc.
 2. Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength for anchor and as tested according to ASTM E488/E488M.
- B. Adhesive Anchor Bolts:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. DeWALT.
 - b. Hilti, Inc.
 - c. Simpson Strong-Tie Co., Inc.
 2. Drilled-in and capsule anchor system containing PVC or urethane methacrylate-based resin and accelerator, or injected polymer or hybrid mortar adhesive. Provide anchor bolts and hardware with zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E488/E488M.

- C. Provide post-installed concrete anchors that have been prequalified for use in wind-load applications. Post-installed concrete anchors must comply with all requirements of ASCE/SEI 7-16, Ch. 13.
 - 1. Prequalify post-installed anchors in concrete in accordance with ACI 355.2 or other approved qualification testing procedures.
 - 2. Prequalify post-installed anchors in masonry in accordance with approved qualification procedures.
- D. Expansion-type anchor bolts are not permitted for equipment in excess of 10 hp that is not vibration isolated.
 - 1. Undercut expansion anchors are permitted.

2.19 CONCRETE INSERTS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. DeWALT.
 - 2. Gripple, Inc.
 - 3. Hilti, Inc.
 - 4. International Seismic Application Technology (ISAT).
 - 5. Simpson Strong-Tie Co., Inc.
- B. Provide preset concrete inserts that are prequalified in accordance with ICC-ES AC466 testing.
- C. Comply with ANSI/MSS SP-58.

2.20 VIBRATION ISOLATION EQUIPMENT BASES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Kinetics Noise Control, Inc.
 - 2. Mason Industries, Inc.
 - 3. Vibration Eliminator Co., Inc.
 - 4. Vibration Mountings & Controls, Inc.
 - 5. Vibro-Acoustics.
- B. Steel Rails: Factory-fabricated, welded, structural-steel rails: SR.
 - 1. Design Requirements: Lowest possible mounting height with not less than 1-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide rails.
 - a. Include supports for suction and discharge elbows for pumps.
 - 2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A36/A36M. Rails shall have shape to accommodate supported equipment.
 - 3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

- C. Steel Bases: Factory-fabricated, welded, structural-steel bases and rails: SB.
 - 1. Design Requirements: Lowest possible mounting height with not less than 1-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.
 - a. Include supports for suction and discharge elbows for pumps.
 - 2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A36/A36M. Bases shall have shape to accommodate supported equipment.
 - 3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.
- D. Concrete Inertia Base: Factory-fabricated, welded, structural-steel bases and rails ready for placement of cast-in-place concrete: CIB.
 - 1. Design Requirements: Lowest possible mounting height with not less than 1-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.
 - a. Include supports for suction and discharge elbows for pumps.
 - 2. Structural Steel: Steel shapes, plates, and bars complying with ASTM A36/A36M. Bases shall have shape to accommodate supported equipment.
 - 3. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.
 - 4. Fabrication: Fabricate steel templates to hold equipment anchor-bolt sleeves and anchors in place during placement of concrete. Obtain anchor-bolt templates from supported equipment manufacturer.
 - 5. The weight of each inertia base shall be sufficient to lower the center of gravity to or below the isolator support plane for installations with wind loading requirements. For non-wind loaded conditions weight of each base shall be at least equal to the weight of the equipment mounted thereon.
 - 6. Inertia bases shall be a minimum of 6" thick.

2.21 RESTRAINED ISOLATION ROOF-CURB RAILS

- A. Spring Isolation Curbs: SC.
- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Kinetics Noise Control, Inc.
 - 2. Mason Industries, Inc.
 - 3. Vibration Eliminator Co., Inc.
 - 4. Vibration Mountings & Controls, Inc.
 - 5. Vibro-Acoustics.
- C. Description: Factory-assembled, fully enclosed, air- and watertight curb rail designed to resiliently support equipment.
- D. Upper Frame: Shall provide continuous and captive support for equipment and to be captive to resiliently resist wind forces.
- E. Lower Support Assembly: Containing adjustable and removable steel springs that support upper frame. Lower support assembly shall have a means for attaching to building structure or a wood nailer for attaching

roof materials and shall be insulated to achieve thermal performance as required of rigid glass-fiber insulation on inside of assembly.

1. Adjustable, restrained-spring isolators shall be mounted with elastomeric vibration isolation pads and shall have access ports, for level adjustment, with removable waterproof covers at all isolator locations. Isolators shall be located so they are accessible for adjustment at any time during the life of the installation without interfering with integrity of roof.
- F. Water Seal: Galvanized sheet metal with EPDM seals at corners, attached to upper support frame, extending down past lower support assembly, and counterflashed over roof materials.

2.22 ELASTOMERIC CURB ISOLATION

A. Elastomeric Curb Isolation Pad: ECIP.

1. Manufacturer: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - e. Vibro-Acoustics.
2. Description: Elastomeric curb isolation pad installed between roof mounted equipment and supporting curb.
3. Minimum 0.5" elastomeric layer thickness.
4. Minimum 1.75" elastomeric layer width.
5. 40-60 durometer neoprene or high density compressed molded fiberglass individually coated with a flexible moisture impervious membrane.
6. Elastomeric layer surface finish shall allow a weather proofed seal at top and bottom joint.
7. Adhered to curb and equipment with mastic adhesive without need of rigid connection. Sealed weather tight at all joints with silicone caulk.

2.23 FLEXIBLE CONNECTORS

A. Flexible Elastomeric Pipe Connectors

1. Manufacturer: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - e. Vibro-Acoustics.
2. Single-sphere and twin-sphere types, made of multiple plies of nylon cord fabric and neoprene, hydraulically molded.
3. Connectors through 1.5" shall have threaded ends. Connectors 2" and large shall have flanged ends with recessed groove to receive the connector's raised neoprene face.
4. Connectors 4" and larger operating above 100 psig, and any sizes and pressures as required by flex connector manufacturer, shall have isolated limit stops to prevent overextension and overcompression.

5. Limit stops shall be either control cables with neoprene isolated end fitting and anti-compression stops, control rods with neoprene isolation washers and bushings, or spring isolated control units.
6. Connectors shall be line size and shall be designed for the pressures and temperatures encountered in the system, minimum 150 psig and 250° F.

B. Flexible Metal Hose Connectors

1. Manufacturer: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - e. Vibro-Acoustics.
2. Stainless steel corrugated type with stainless steel woven braid outer sheath.
3. Minimum Live Lengths:
 - a. Pipe diameters up to 2.5" - 12" minimum live length.
 - b. Pipe diameters 3" to 4" - 18" minimum live length.
 - c. Pipe diameters 5" to 10" - 24" minimum live length.
 - d. Pipe diameters 12" or greater - 36" minimum live length.

C. Flexible Duct Connector

1. Manufacturer: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Duro-Dyne.
 - c. Ventfabrics.
2. Fabric, fiberglass, or EPDM flexible connections.
3. Connections shall comply with NFPA 90A-2018, NFPA 701-2019, and shall be asbestos-free and designed for continuous use at 275° F.
4. Connections to laboratory exhaust equipment shall be designed for use with acidic fumes.
5. Connections exposed to weather shall be sunlight and ozone resistant.
6. Flexible sections shall be wide enough to allow at least 2" of flexible separation in installed conditions.

2.24 THRUST RESTRAINTS

A. Spring Thrust Restraints

1. Manufacturer: Subject to compliance with requirements, provide products by one of the following:
 - a. Kinetics Noise Control, Inc.
 - b. Mason Industries, Inc.
 - c. Vibration Eliminator Co., Inc.
 - d. Vibration Mountings & Controls, Inc.
 - e. Vibro-Acoustics.

2. A set (2 or more per installation location) of spring thrust resisting assemblies consisting of coil springs, spring retainers, isolation washers, angle mounting brackets, and elastomeric tubing for isolating thrust rods.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and equipment to receive vibration isolation and wind-load control devices for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in of reinforcement and cast-in-place anchors to verify actual locations before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATIONS

- A. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by an agency acceptable to authorities having jurisdiction.
- B. Hanger-Rod Stiffeners: Install hanger-rod stiffeners where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods due to wind-load forces.
- C. Strength of Support Assemblies: Where not indicated, select sizes of components so strength is adequate to carry static and wind force loads within specified loading limits.

3.3 INSTALLATION OF VIBRATION AND WIND-LOAD CONTROL DEVICES

- A. Provide vibration and wind-load control devices for systems and equipment where indicated in Equipment Schedules or Vibration-Control Device Schedules on Drawing Plans, General Notes, Schedules, and/or Details, where Specifications indicate they are to be installed on specific equipment and systems, and where required by applicable codes.
- B. Coordinate location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in Section 033000 "Cast-in-Place Concrete."
- C. Installation of vibration isolators and wind-load restraints must not cause any change of position of equipment, piping, or ductwork resulting in stresses or misalignment.
- D. Comply with requirements in Section 077200 "Roof Accessories" for installation of roof curbs, equipment supports, and roof penetrations.
- E. Equipment Restraints:
 1. Install snubbers on HVAC equipment mounted on vibration isolators. Locate snubbers as close as possible to vibration isolators and bolt to equipment base and supporting structure.
 2. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.

3. Install wind-load-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction that provides required submittals for component.

F. Piping Restraints:

1. Comply with requirements in MSS SP-127.
2. Space lateral supports a maximum of 40 feet o.c., and longitudinal supports a maximum of 80 feet o.c.
3. Brace a change of direction longer than 12 feet.

G. Install wind-load-restraint cables so they do not bend across edges of adjacent equipment or building structure.

H. Install wind-load-restraint devices using methods approved by agency acceptable to authorities having jurisdiction that provides required submittals for component.

I. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolt and mounting hole in concrete base.

J. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.

K. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.

L. Post-Installed Concrete Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Wedge-Type Anchor Bolts: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Adhesive-Type Anchor Bolts: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
5. Set anchors to manufacturer's recommended torque, using a torque wrench.
6. Install zinc-coated steel anchors for interior and stainless steel anchors for exterior applications.

3.4 ACCOMMODATION OF DIFFERENTIAL MOTION

- A. Provide flexible connections in piping systems where they cross structural joints and other point where differential movement may occur. Provide adequate flexibility to accommodate differential movement as determined in accordance with ASCE/SEI 7.

3.5 INSTALLATION OF VIBRATION ISOLATION EQUIPMENT BASES

- A. Coordinate location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in Section 033000 "Cast-in-Place Concrete."
- B. Coordinate dimensions of equipment bases with requirements of isolated equipment specified in this and other Sections. Where dimensions of base are indicated on Drawings, they may require adjustment to accommodate isolated equipment.

3.6 ADJUSTING

- A. Adjust isolators after system is at operating weight.
- B. Adjust limit stops on restrained-spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.

END OF SECTION 230548.13

SECTION 230553 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. Equipment labels.
 - 2. Pipe labels.
 - 3. Valve tags.

1.2 ACTION SUBMITTALS

- A. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1 EQUIPMENT LABELS

- A. Plastic Labels for Equipment:
 - 1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, with predrilled holes for attachment hardware.
 - 2. Letter and Background Color: As indicated for specific application under Part 3.
 - 3. Maximum Temperature: Able to withstand temperatures of up to 160 deg F.
 - 4. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
 - 5. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances of up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
 - 6. Fasteners: Stainless steel rivets or self-tapping screws.
 - 7. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- B. Label Content: Include equipment's Drawing designation or unique equipment number, Drawing numbers where equipment is indicated (plans, details, and schedules), and the Specification Section number and title where equipment is specified.

2.2 PIPE LABELS

- A. General Requirements for Manufactured Pipe Labels: Preprinted, color coded, with lettering indicating service and showing flow direction in accordance with ASME A13.1.
- B. Letter and Background Color: As indicated for specific application under Part 3.
- C. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to partially cover circumference of pipe and to attach to pipe without fasteners or adhesive.

- D. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings. Also include:
 - 1. Pipe size.
 - 2. Flow-Direction Arrows: Include flow-direction arrows on main distribution piping. Arrows may be either integral with label or applied separately.
 - 3. Lettering Size: Size letters in accordance with ASME A13.1 for piping.

2.3 VALVE TAGS

- A. Description: Stamped or engraved with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers.
 - 1. Tag Material: Brass, 0.04-inch minimum thickness, with predrilled or stamped holes for attachment hardware.
 - 2. Fasteners: Brass link chain.
- B. Letter and Background Color: As indicated for specific application under Part 3.
- C. Valve Schedules: For each piping system, on 8-1/2-by-11-inch bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.
 - 1. Include valve-tag schedule in operation and maintenance data.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Clean piping and equipment surfaces of incompatible primers, paints, and encapsulants, as well as dirt, oil, grease, release agents, and other substances that could impair bond of identification devices.

3.2 INSTALLATION, GENERAL REQUIREMENTS

- A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
- B. Coordinate installation of identifying devices with locations of access panels and doors.
- C. Install identifying devices before installing acoustical ceilings and similar concealment.
- D. Locate identifying devices so that they are readily visible from the point of normal approach.

3.3 INSTALLATION OF EQUIPMENT LABELS, WARNING SIGNS, AND LABELS

- A. Permanently fasten labels on each item of mechanical equipment.

- B. Sign and Label Colors:
 - 1. White letters on an ANSI Z535.1 safety-blue background.
- C. Locate equipment labels where accessible and visible.
- D. Arc-Flash Warning Signs: Provide arc-flash warning signs on electrical disconnects and other equipment where arc-flash hazard exists, as indicated on Drawings, and in accordance with requirements of OSHA and NFPA 70E.

3.4 INSTALLATION OF PIPE LABELS

- A. Install pipe labels showing service and flow direction with permanent adhesive on pipes.
- B. Stenciled Pipe Label Option: Stenciled labels showing service and flow direction may be provided instead of manufactured pipe labels, at Installer's option. Install stenciled pipe labels, complying with ASME A13.1, with painted, color-coded bands or rectangles on each piping system.
 - 1. Identification Paint: Use for contrasting background.
 - 2. Stencil Paint: Use for pipe marking.
- C. Pipe-Label Locations: Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:
 - 1. Within 3 ft. of each valve and control device.
 - 2. At access doors, manholes, and similar access points that permit view of concealed piping.
 - 3. Within 3 ft. of equipment items and other points of origination and termination.
 - 4. Spaced at maximum intervals of 25 ft. along each run. Reduce intervals to 10 ft. in areas of congested piping, ductwork, and equipment.
- D. Do not apply plastic pipe labels or plastic tapes directly to bare pipes conveying fluids at temperatures of 125 deg F or higher. Where these pipes are to remain uninsulated, use a short section of insulation or use stenciled labels.
- E. Flow-Direction Arrows: Use arrows to indicate direction of flow in pipes, including pipes where flow is allowed in both directions.
- F. Pipe-Label Color Schedule:
 - 1. Chilled-Water Piping: White letters on an ANSI Z535.1 safety-green background.
 - 2. Heating Water Piping: White letters on an ANSI Z535.1 safety-green background.
 - 3. Refrigerant Piping: White letters on an ANSI Z535.1 safety-blue background.

3.5 INSTALLATION OF VALVE TAGS

- A. Install tags on valves and control devices in piping systems, except check valves, valves within factory-fabricated equipment units, shutoff valves, and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule in the operating and maintenance manual.

- B. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in "Valve-Tag Size and Shape" Subparagraph below.
1. Valve-Tag Size and Shape:
 - a. Chilled Water: 1-1/2 inches , round.
 - b. Hot Water: 1-1/2 inches , round.
 2. Valve-Tag Colors:
 - a. For each piping system, use the same lettering and background coloring system on valve tags as used for the Pipe Label Schedule text and background.

END OF SECTION 230553

SECTION 230593 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

- 1. Testing, Adjusting, and Balancing of Air Systems:
 - a. Constant-volume air systems.
 - b. Variable-air-volume systems.
 - c. Multizone systems.
- 2. Testing, Adjusting, and Balancing of Hydronic Piping Systems:
 - a. Variable-flow hydronic systems.
 - b. Primary-secondary hydronic systems.
- 3. Testing, adjusting, and balancing of fuel oil systems for HVAC.
- 4. Testing, adjusting, and balancing of steam and condensate piping systems.
- 5. Testing, adjusting, and balancing of equipment.
- 6. Duct leakage tests verification.
- 7. Pipe leakage tests verification.
- 8. HVAC-control system verification.

1.3 DEFINITIONS

- A. AABC: Associated Air Balance Council.
- B. NEBB: National Environmental Balancing Bureau.
- C. TAB: Testing, adjusting, and balancing.
- D. TABB: Testing, Adjusting, and Balancing Bureau.
- E. TAB Specialist: An independent entity meeting qualifications to perform TAB work.
- F. TDH: Total dynamic head.
- G. UFAD: Underfloor air distribution.

1.4 PREINSTALLATION MEETINGS

- A. TAB Conference: Conduct a TAB conference at Project site (other) after approval of the TAB strategies and procedures plan, to develop a mutual understanding of the details. Provide a minimum of 14 (other) days' advance notice of scheduled meeting time and location.
 - 1. Minimum Agenda Items:
 - a. The Contract Documents examination report.
 - b. The TAB plan.
 - c. Needs for coordination and cooperation of trades and subcontractors.
 - d. Proposed procedures for documentation and communication flow.

1.5 ACTION SUBMITTALS

- A. Sustainable Design Submittals:
 - 1. Air-Balance Report: Documentation indicating that Work complies with ASHRAE 62.1, Section 7.2.2 - "Air Balancing."
 - 2. TAB Report: Documentation indicating that Work complies with ASHRAE/IES 90.1, Section 6.7.2.3 - "System Balancing."

1.6 INFORMATIONAL SUBMITTALS

- A. Qualification Data: Within 30 60 90 (other) days of Contractor's Notice to Proceed, submit documentation that the TAB specialist and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.
- B. Contract Documents Examination Report: Within 30 60 90 (other) days of Contractor's Notice to Proceed, submit the Contract Documents review report, as specified in Part 3.
- C. Strategies and Procedures Plan: Within 30 60 90 (other) days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures, as specified in "Preparation" Article.
- D. System Readiness Checklists: Within 30 60 90 (other) days of Contractor's Notice to Proceed, submit system readiness checklists, as specified in "Preparation" Article.
- E. Examination Report: Submit a summary report of the examination review required in "Examination" Article.
- F. Certified TAB reports.
- G. Sample report forms.
- H. Instrument calibration reports, to include the following:
 - 1. Instrument type and make.
 - 2. Serial number.
 - 3. Application.
 - 4. Dates of use.
 - 5. Dates of calibration.

1.7 QUALITY ASSURANCE

- A. TAB Specialists Qualifications, Certified by AABC:
 - 1. TAB Field Supervisor: Employee of the TAB specialist and certified by AABC.
 - 2. TAB Technician: Employee of the TAB specialist and certified by AABC.
- B. TAB Specialists Qualifications, Certified by NEBB or TABB:
 - 1. TAB Field Supervisor: Employee of the TAB specialist and certified by NEBB or TABB.
 - 2. TAB Technician: Employee of the TAB specialist and certified by NEBB or TABB.
- C. Instrumentation Type, Quantity, Accuracy, and Calibration: Comply with requirements in ASHRAE 111, Section 4, "Instrumentation."
 - 1. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."
- D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6.7.2.3 - "System Balancing."
- E. Code and AHJ Compliance: TAB is required to comply with governing codes and requirements of authorities having jurisdiction.

1.8 FIELD CONDITIONS

- A. Full Owner Occupancy: Owner will occupy the site and existing building during entire TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.
- B. Partial Owner Occupancy: Owner may occupy completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 TAB SPECIALISTS

- A. Subject to compliance with requirements, engage one of the following available TAB specialists that may be engaged include, but are not limited to, the following:
 - 1. (other).

3.2 EXAMINATION

- A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems designs that may preclude proper TAB of systems and equipment.

- B. Examine installed systems for balancing devices, such as test ports, gauge cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are applicable for intended purpose and are accessible.
- C. Examine the approved submittals for HVAC systems and equipment.
- D. Examine design data, including HVAC system descriptions, statements of design assumptions for environmental conditions and systems output, and statements of philosophies and assumptions about HVAC system and equipment controls.
- E. Examine ceiling plenums and underfloor air plenums used for HVAC to verify that they are properly separated from adjacent areas and sealed.
- F. Examine equipment performance data, including fan and pump curves.
 - 1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
 - 2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.
- G. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.
- H. Examine test reports specified in individual system and equipment Sections.
- I. Examine HVAC equipment and verify that bearings are greased, belts are aligned and tight, filters are clean, and equipment with functioning controls is ready for operation.
- J. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.
- K. Examine temporary and permanent strainers. Verify that temporary strainer screens used during system cleaning and flushing have been removed and permanent strainer baskets are installed and clean.
- L. Examine control valves for proper installation for their intended function of isolating, throttling, diverting, or mixing fluid flows.
- M. Examine heat-transfer coils for correct piping connections and for clean and straight fins.
- N. Examine system pumps to ensure absence of entrained air in the suction piping.
- O. Examine operating safety interlocks and controls on HVAC equipment.
- P. Examine control dampers for proper installation for their intended function of isolating, throttling, diverting, or mixing air flows.
- Q. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.3 PREPARATION

- A. Prepare a TAB plan that includes the following:
 - 1. Equipment and systems to be tested.
 - 2. Strategies and step-by-step procedures for balancing the systems. Include proposed locations for duct traverses.
 - 3. Instrumentation to be used.
 - 4. Sample forms with specific identification for all equipment.
- B. Perform system-readiness checks of HVAC systems and equipment to verify system readiness for TAB work. Include, at a minimum, the following:
 - 1. Airside:
 - a. Verify that leakage and pressure tests on air distribution systems have been satisfactorily completed.
 - b. Duct systems are complete with terminals installed.
 - c. Volume, smoke, and fire dampers are open and functional.
 - d. Clean filters are installed.
 - e. Fans are operating, free of vibration, and rotating in correct direction.
 - f. Variable-frequency controllers' startup is complete and safeties are verified.
 - g. Automatic temperature-control systems are operational.
 - h. Ceilings are installed.
 - i. Windows and doors are installed.
 - j. Suitable access to balancing devices and equipment is provided.
 - 2. Hydronics:
 - a. Verify leakage and pressure tests on water distribution systems have been satisfactorily completed.
 - b. Piping is complete with terminals installed.
 - c. Water treatment is complete.
 - d. Systems are flushed, filled, and air purged.
 - e. Strainers are pulled and cleaned.
 - f. Control valves are functioning in accordance with the sequence of operation.
 - g. Shutoff and balance valves have been verified to be 100 percent open.
 - h. Pumps are started and proper rotation is verified.
 - i. Pump gauge connections are installed directly at pump inlet and outlet flanges or in discharge and suction pipe prior to valves or strainers.
 - j. Variable-frequency controllers' startup is complete and safeties are verified.
 - k. Suitable access to balancing devices and equipment is provided.

3.4 GENERAL PROCEDURES FOR TESTING AND BALANCING

- A. Perform testing and balancing procedures on each system in accordance with the procedures contained in AABC's "National Standards for Total System Balance" ASHRAE 111 NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" and in this Section.
- B. Cut insulation, ducts, pipes, and equipment casings for installation of test probes to the minimum extent necessary for TAB procedures.
 - 1. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.

2. After testing and balancing, install test ports and duct access doors that comply with requirements in Section 233300 "Air Duct Accessories."
 3. Where holes for probes are required in piping or hydronic equipment, install pressure and temperature test plugs to seal systems.
 4. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish in accordance with Section 230713 "Duct Insulation," Section 230716 "HVAC Equipment Insulation," and Section 230719 "HVAC Piping Insulation."
- C. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.
- D. Take and report testing and balancing measurements in inch-pound (IP) and metric (SI) units.

3.5 TESTING, ADJUSTING, AND BALANCING OF HVAC EQUIPMENT

- A. Test, adjust, and balance HVAC equipment indicated on Drawings, including, but not limited to, the following:
1. Motors.
 2. Pumps.
 3. Fans and ventilators.
 4. Air curtains.
 5. Terminal units.
 6. Commercial kitchen hoods.
 7. Boilers.
 8. Deaerators.
 9. Furnaces.
 10. Radiant heaters.
 11. Unit heaters.
 12. Solar collectors.
 13. Condensing units.
 14. Condensers.
 15. Energy-recovery units.
 16. Air-handling units.
 17. Heating and ventilating units.
 18. Rooftop air-conditioning units.
 19. Heating-only makeup air units.
 20. Dedicated outdoor-air units.
 21. Packaged air conditioners.
 22. Self-contained air conditioners.
 23. Computer-room air conditioners.
 24. Split-system air conditioners.
 25. Variable-refrigerant-flow systems.
 26. Heat pumps.
 27. Valance heating and cooling units.
 28. Chilled beams.
 29. Coils.
 30. Fan coil units.
 31. Unit ventilators.
 32. Radiators.
 33. Convectors.
 34. Finned-tube radiation heaters.
 35. Radiant-heating cables piping and panels.
 36. Humidifiers.

37. Dehumidification units.

3.6 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

- A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.
- B. Prepare schematic diagrams of systems' Record drawings duct layouts.
- C. For variable-air-volume systems, develop a plan to simulate diversity.
- D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.
- E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.
- F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
- G. Verify that motor starters are equipped with properly sized thermal protection.
- H. Check dampers for proper position to achieve desired airflow path.
- I. Check for airflow blockages.
- J. Check condensate drains for proper connections and functioning.
- K. Check for proper sealing of air-handling-unit components.

3.7 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

- A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
 - 1. Measure total airflow.
 - a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
 - b. Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.
 - c. Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
 - 2. Measure fan static pressures as follows:
 - a. Measure static pressure directly at the fan outlet or through the flexible connection.
 - b. Measure static pressure directly at the fan inlet or through the flexible connection.
 - c. Measure static pressure across each component that makes up the air-handling system.
 - d. Report artificial loading of filters at the time static pressures are measured.
 - 3. Review Contractor-prepared shop drawings and Record drawings to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

4. Obtain approval from Architect Owner Construction Manager Commissioning Authority for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
 5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.
- B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.
1. Measure airflow of submain and branch ducts.
 2. Adjust submain and branch duct volume dampers for specified airflow.
 3. Re-measure each submain and branch duct after all have been adjusted.
- C. Adjust air inlets and outlets for each space to indicated airflows.
1. Set airflow patterns of adjustable outlets for proper distribution without drafts.
 2. Measure inlets and outlets airflow.
 3. Adjust each inlet and outlet for specified airflow.
 4. Re-measure each inlet and outlet after they have been adjusted.
- D. Verify final system conditions.
1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to design if necessary.
 2. Re-measure and confirm that total airflow is within design.
 3. Re-measure all final fan operating data, speed, volts, amps, and static profile.
 4. Mark all final settings.
 5. Test system in economizer mode. Verify proper operation and adjust if necessary.
 6. Measure and record all operating data.
 7. Record final fan-performance data.

3.8 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

- A. Adjust the variable-air-volume systems as follows:
1. Verify that the system static pressure sensor is located two-thirds of the distance down the duct from the fan discharge.
 2. Verify that the system is under static pressure control.
 3. Select the terminal unit that is most critical to the supply-fan airflow. Measure inlet static pressure, and adjust system static pressure control set point so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
 4. Calibrate and balance each terminal unit for maximum and minimum design airflow as follows:
 - a. Adjust controls so that terminal is calling for maximum airflow. Some controllers require starting with minimum airflow. Verify calibration procedure for specific project.
 - b. Measure airflow and adjust calibration factor as required for design maximum airflow. Record calibration factor.
 - c. When maximum airflow is correct, balance the air outlets downstream from terminal units.
 - d. Adjust controls so that terminal is calling for minimum airflow.

- e. Measure airflow and adjust calibration factor as required for design minimum airflow. Record calibration factor. If no minimum calibration is available, note any deviation from design airflow.
 - f. On constant volume terminals, in critical areas where room pressure is to be maintained, verify that the airflow remains constant over the full range of full cooling to full heating. Note any deviation from design airflow or room pressure.
- 5. After terminals have been calibrated and balanced, test and adjust system for total airflow. Adjust fans to deliver total design airflows within the maximum allowable fan speed listed by fan manufacturer.
 - a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
 - b. Set terminals for maximum airflow. If system design includes diversity, adjust terminals for maximum and minimum airflow, so that connected total matches fan selection and simulates actual load in the building.
 - c. Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.
 - d. Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
- 6. Measure fan static pressures as follows:
 - a. Measure static pressure directly at the fan outlet or through the flexible connection.
 - b. Measure static pressure directly at the fan inlet or through the flexible connection.
 - c. Measure static pressure across each component that makes up the air-handling system.
 - d. Report any artificial loading of filters at the time static pressures are measured.
- 7. Set final return and outside airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.
 - a. Balance the return-air ducts and inlets.
 - b. Verify that terminal units are meeting design airflow under system maximum flow.
- 8. Re-measure the inlet static pressure at the most critical terminal unit, and adjust the system static pressure set point to the most energy-efficient set point to maintain the optimum system static pressure. Record set point and give to controls Contractor.
- 9. Verify final system conditions as follows:
 - a. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.
 - b. Re-measure and confirm that total airflow is within design.
 - c. Re-measure final fan operating data, speed, volts, amps, and static profile.
 - d. Mark final settings.
 - e. Test system in economizer mode. Verify proper operation and adjust if necessary. Measure and record all operating data.
 - f. Verify tracking between supply and return fans.

3.9 PROCEDURES FOR MULTIZONE SYSTEMS

- A. Position the unit's automatic zone dampers for maximum flow through the cooling coil.

- B. The procedures for multizone systems will utilize the zone balancing dampers to achieve the indicated airflow within the zone.
- C. After balancing, place the unit's automatic zone dampers for maximum heating flow. Retest zone airflows and record any variances.
- D. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
 - 1. Measure total airflow.
 - a. Set outside-air, return-air and relief-air dampers for proper position that simulates minimum outdoor air conditions.
 - b. Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.
 - c. Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.
 - 2. Measure fan static pressures as follows:
 - a. Measure static pressure directly at the fan outlet or through the flexible connection.
 - b. Measure static pressure directly at the fan inlet or through the flexible connection.
 - c. Measure static pressure across each component that makes up the air-handling system.
 - d. Report artificial loading of filters at the time static pressures are measured.
 - 3. Review Record drawings to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
 - 4. Obtain approval from Architect Owner Construction Manager Commissioning Authority for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
 - 5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.
- E. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.
 - 1. Measure airflow of submain and branch ducts.
 - 2. Adjust submain and branch duct volume dampers for specified airflow.
 - 3. Re-measure each submain and branch duct after all have been adjusted.
- F. Adjust air inlets and outlets for each space to indicated airflows.
 - 1. Set airflow patterns of adjustable outlets for proper distribution without drafts.
 - 2. Measure inlet and outlet airflow.
 - 3. Adjust each inlet and outlet for specified airflow.
 - 4. Re-measure each inlet and outlet after they have been adjusted.
- G. Verify final system conditions.
 - 1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.

2. Re-measure and confirm that total airflow is within design.
3. Re-measure all final fan operating data, speed, volts, amps, and static profile.
4. Mark all final settings.
5. Test system in economizer mode. Verify proper operation and adjust if necessary.
6. Measure and record all operating data.
7. Record final fan-performance data.

3.10 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

- A. Prepare test reports for pumps, coils, and other equipment. Obtain approved submittals and manufacturer-recommended testing procedures. Crosscheck the summation of required coil and equipment flow rates with pump design flow rate.
- B. Prepare schematic diagrams of systems' Record drawings piping layouts.
- C. In addition to requirements in "Preparation" Article, prepare hydronic systems for testing and balancing as follows:
 1. Check expansion tank for proper setting.
 2. Check highest vent for adequate pressure.
 3. Check flow-control valves for proper position.
 4. Locate start-stop and disconnect switches, electrical interlocks, and motor controllers.
 5. Verify that motor controllers are equipped with properly sized thermal protection.
 6. Check that air has been purged from the system.
- D. Measure and record upstream and downstream pressure of each piece of equipment.
- E. Measure and record upstream and downstream pressure of pressure-reducing valves.
- F. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.
 1. Check settings and operation of each safety valve. Record settings.

3.11 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

- A. Balance systems with automatic two- and three-way control valves by setting systems at maximum flow through heat-exchange terminals, and proceed as specified above for hydronic systems.
- B. Adjust the variable-flow hydronic system as follows:
 1. Verify that the pressure-differential sensor(s) is located as indicated.
 2. Determine whether there is diversity in the system.
- C. For systems with no flow diversity:
 1. Adjust pumps to deliver total design flow.
 - a. Measure total water flow.
 - 1) Position valves for full flow through coils.
 - 2) Measure flow by main flow meter, if installed and after field calibration has been verified and documented.

- 3) If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.
 - b. Measure pump TDH as follows:
 - 1) Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
 - 2) Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
 - 3) Convert pressure to head and correct for differences in gauge heights.
 - 4) Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.
 - 5) With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.
 - c. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.
2. Adjust flow-measuring devices installed in mains and branches to design water flows.
 - a. Measure flow in main and branch pipes.
 - b. Adjust main and branch balance valves for design flow.
 - c. Re-measure each main and branch after all have been adjusted.
3. Adjust flow-measuring devices installed at terminals for each space to design water flows.
 - a. Measure flow at terminals.
 - b. Adjust each terminal to design flow.
 - c. Re-measure each terminal after it is adjusted.
 - d. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
 - e. Perform temperature tests after flows have been balanced.
4. For systems with pressure-independent valves at terminals:
 - a. Measure differential pressure and verify that it is within manufacturer's specified range.
 - b. Perform temperature tests after flows have been verified.
5. For systems without pressure-independent valves or flow-measuring devices at terminals:
 - a. Measure and balance coils by either coil pressure drop or temperature method.
 - b. If balanced by coil pressure drop, perform temperature tests after flows have been verified.
6. Prior to verifying final system conditions, determine the system pressure-differential set point(s).
7. If the pump discharge valve was used to set total system flow with variable-frequency controller at 60 Hz, at completion, open discharge valve 100 percent, and allow variable-frequency controller to control system differential-pressure set point. Record pump data under both conditions.
8. Mark final settings and verify that all memory stops have been set.
9. Verify final system conditions as follows:
 - a. Re-measure and confirm that total flow is within design.
 - b. Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.
 - c. Mark final settings.

D. For systems with flow diversity:

1. Determine diversity factor.
2. Simulate system diversity by closing required number of control valves, as approved by Architect.
3. Adjust pumps to deliver total design flow.
 - a. Measure total water flow.
 - 1) Position valves for full flow through coils.
 - 2) Measure flow by main flow meter, if installed and after field calibration has been verified and documented.
 - 3) If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.
 - b. Measure pump TDH as follows:
 - 1) Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
 - 2) Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
 - 3) Convert pressure to head and correct for differences in gauge heights.
 - 4) Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.
 - 5) With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.
 - c. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.
4. Adjust flow-measuring devices installed in mains and branches to design water flows.
 - a. Measure flow in main and branch pipes.
 - b. Adjust main and branch balance valves for design flow.
 - c. Re-measure each main and branch after all have been adjusted.
5. Adjust flow-measuring devices installed at terminals for each space to design water flows.
 - a. Measure flow at terminals.
 - b. Adjust each terminal to design flow.
 - c. Re-measure each terminal after it is adjusted.
 - d. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
 - e. Perform temperature tests after flows have been balanced.
6. For systems with pressure-independent valves at terminals:
 - a. Measure differential pressure, and verify that it is within manufacturer's specified range.
 - b. Perform temperature tests after flows have been verified.
7. For systems without pressure-independent valves or flow-measuring devices at terminals:
 - a. Measure and balance coils by either coil pressure drop or temperature method.
 - b. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

8. Open control valves that were shut. Close a sufficient number of control valves that were previously open to maintain diversity, and balance terminals that were just opened.
9. Prior to verifying final system conditions, determine system pressure-differential set point(s).
10. If the pump discharge valve was used to set total system flow with variable-frequency controller at 60 Hz, at completion, open discharge valve 100 percent, and allow variable-frequency controller to control system differential-pressure set point. Record pump data under both conditions.
11. Mark final settings and verify that memory stops have been set.
12. Verify final system conditions as follows:
 - a. Re-measure and confirm that total water flow is within design.
 - b. Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.
 - c. Mark final settings.

3.12 PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS

- A. Balance the primary circuit flow first.
- B. Balance the secondary circuits after the primary circuits are complete.
- C. Adjust pumps to deliver total design flow.
 1. Measure total water flow.
 - a. Position valves for full flow through coils.
 - b. Measure flow by main flow meter, if installed and after field calibration has been verified and documented.
 - c. If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.
 2. Measure pump TDH as follows:
 - a. Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
 - b. Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
 - c. Convert pressure to head and correct for differences in gauge heights.
 - d. Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.
 - e. With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.
 3. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.
- D. Adjust flow-measuring devices installed in mains and branches to design water flows.
 1. Measure flow in main and branch pipes.
 2. Adjust main and branch balance valves for design flow.
 3. Re-measure each main and branch after all have been adjusted.

- E. Adjust flow-measuring devices installed at terminals for each space to design water flows.
 - 1. Measure flow at terminals.
 - 2. Adjust each terminal to design flow.
 - 3. Re-measure each terminal after it is adjusted.
 - 4. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
 - 5. Perform temperature tests after flows have been balanced.
- F. For systems with pressure-independent valves at terminals:
 - 1. Measure differential pressure and verify that it is within manufacturer's specified range.
 - 2. Perform temperature tests after flows have been verified.
- G. For systems without pressure-independent valves or flow-measuring devices at terminals:
 - 1. Measure and balance coils by either coil pressure drop or temperature method.
 - 2. If balanced by coil pressure drop, perform temperature tests after flows have been verified.
- H. Verify final system conditions as follows:
 - 1. Re-measure and confirm that total water flow is within design.
 - 2. Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.
 - 3. Mark final settings.
- I. Verify that memory stops have been set.

3.13 PROCEDURES FOR STEAM AND CONDENSATE SYSTEMS

- A. Measure and record upstream and downstream pressure of each piece of equipment.
- B. Measure and record upstream and downstream steam pressure of pressure-reducing valves.
- C. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.
- D. Check settings and operation of each safety valve. Record settings.
- E. Verify the operation of each steam trap.

3.14 PROCEDURES FOR MOTORS

- A. Motors 1/2 (other) HP and Larger: Test at final balanced conditions and record the following data:
 - 1. Manufacturer's name, model number, and serial number.
 - 2. Motor horsepower rating.
 - 3. Motor rpm.
 - 4. Phase and hertz.
 - 5. Nameplate and measured voltage, each phase.
 - 6. Nameplate and measured amperage, each phase.
 - 7. Starter size and thermal-protection-element rating.
 - 8. Service factor and frame size.

- B. Motors Driven by Variable-Frequency Controllers: Test manual bypass of controller to prove proper operation.

3.15 PROCEDURES FOR WATER CHILLERS

- A. Air-Cooled Chillers: Balance water flow through each evaporator to within specified tolerances of indicated flow, with all pumps operating. With only one chiller operating in a multiple-chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:
 - 1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
 - 2. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
 - 3. Power factor if factory-installed instrumentation is furnished for measuring kilowatts.
 - 4. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.
 - 5. Capacity: Calculate in tons kilowatts (other) of cooling.
 - 6. Efficiency: Calculate operating efficiency for comparison to submitted equipment.
 - 7. Verify condenser-fan rotation and record fan and motor data, including number of fans and entering- and leaving-air temperatures.

3.16 PROCEDURES FOR AIR-COOLED CONDENSING UNITS

- A. Verify proper rotation of fan(s).
- B. Measure and record entering- and leaving-air temperatures.
- C. Measure and record entering and leaving refrigerant pressures.
- D. Measure and record operating data of compressor(s), fan(s), and motors.

3.17 PROCEDURES FOR AIR-COOLED CONDENSERS

- A. Verify proper rotation of fan(s).
- B. Measure and record entering- and leaving-air temperatures.
- C. Measure and record entering and leaving refrigerant pressures.
- D. Measure and record operating data of fan(s) and motor(s).

3.18 PROCEDURES FOR BOILERS

- A. Hydronic Boilers:
 - 1. Measure and record entering- and leaving-water temperatures.
 - 2. Measure and record water flow.
 - 3. Measure and record pressure drop.
 - 4. Measure and Record relief valve(s) pressure setting.
 - 5. Capacity: Calculate in Btu/h of heating output.

6. Fuel Consumption: If boiler fuel supply is equipped with flow meter, measure and record consumption.
7. Efficiency: Calculate operating efficiency for comparison to submitted equipment.
8. Fan, motor, and motor controller operating data.

3.19 DUCT LEAKAGE TESTS

- A. Witness the duct leakage testing performed by Installer.
- B. Verify that proper test methods are used and that leakage rates are within specified limits.
- C. Report deficiencies observed.

3.20 PIPE LEAKAGE TESTS

- A. Witness the pipe pressure testing performed by Installer.
- B. Verify that proper test methods are used and that leakage rates are within specified limits.
- C. Report deficiencies observed.

3.21 HVAC CONTROLS VERIFICATION

- A. In conjunction with system balancing, perform the following:
 1. Verify HVAC control system is operating within the design limitations.
 2. Confirm that the sequences of operation are in compliance with Contract Documents.
 3. Verify that controllers are calibrated and function as intended.
 4. Verify that controller set points are as indicated.
 5. Verify the operation of lockout or interlock systems.
 6. Verify the operation of valve and damper actuators.
 7. Verify that controlled devices are properly installed and connected to correct controller.
 8. Verify that controlled devices travel freely and are in position indicated by controller: open, closed, or modulating.
 9. Verify location and installation of sensors to ensure that they sense only intended temperature, humidity, or pressure.
- B. Reporting: Include a summary of verifications performed, remaining deficiencies, and variations from indicated conditions.

3.22 TOLERANCES

- A. Set HVAC system's airflow rates and water flow rates within the following tolerances:
 1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus or minus 10 percent Plus 10 percent or minus 5 percent (other). If design value is less than 100 cfm, within 10 cfm.
 2. Air Outlets and Inlets: Plus or minus 10 percent Plus 10 percent or minus 5 percent (other). If design value is less than 100 cfm, within 10 cfm.
 3. Heating-Water Flow Rate: Plus or minus 5 percent Plus or minus 10 percent Plus 10 percent or minus 5 percent (other). If design value is less than 10 gpm, within 10 percent.

4. Chilled-Water Flow Rate: Plus or minus 5 percent Plus or minus 10 percent Plus 10 percent or minus 5 percent (other). If design value is less than 10 gpm, within 10 percent.
5. Condenser-Water Flow Rate: Plus or minus 5 percent Plus or minus 10 percent Plus 10 percent or minus 5 percent (other).

- B. Maintaining pressure relationships as designed shall have priority over the tolerances specified above.

3.23 PROGRESS REPORTING

- A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for system-balancing devices. Recommend changes and additions to system-balancing devices, to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance-measuring and -balancing devices.
- B. Status Reports: Prepare weekly biweekly monthly (other) progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.24 FINAL REPORT

- A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.
1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
 2. Include a list of instruments used for procedures, along with proof of calibration.
 3. Certify validity and accuracy of field data.
- B. Final Report Contents: In addition to certified field-report data, include the following:
1. Pump curves.
 2. Fan curves.
 3. Manufacturers' test data.
 4. Field test reports prepared by system and equipment installers.
 5. Other information relative to equipment performance; do not include Shop Drawings and Product Data.
- C. General Report Data: In addition to form titles and entries, include the following data:
1. Title page.
 2. Name and address of the TAB specialist.
 3. Project name.
 4. Project location.
 5. Architect's name and address.
 6. Engineer's name and address.
 7. Contractor's name and address.
 8. Report date.
 9. Signature of TAB supervisor who certifies the report.
 10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.

11. Summary of contents, including the following:
 - a. Indicated versus final performance.
 - b. Notable characteristics of systems.
 - c. Description of system operation sequence if it varies from the Contract Documents.
12. Nomenclature sheets for each item of equipment.
13. Data for terminal units, including manufacturer's name, type, size, and fittings.
14. Notes to explain why certain final data in the body of reports vary from indicated values.
15. Test conditions for fans performance forms, including the following:
 - a. Settings for outdoor-, return-, and exhaust-air dampers.
 - b. Conditions of filters.
 - c. Cooling coil, wet- and dry-bulb conditions.
 - d. Heating coil, dry-bulb conditions.
 - e. Face and bypass damper settings at coils.
 - f. Fan drive settings, including settings and percentage of maximum pitch diameter.
 - g. Variable-frequency controller Inlet vane settings for variable-air-volume systems.
 - h. Settings for pressure controller(s).
 - i. Other system operating conditions that affect performance.
16. Test conditions for pump performance forms, including the following:
 - a. Variable-frequency controller settings for variable-flow hydronic systems.
 - b. Settings for pressure controller(s).
 - c. Other system operating conditions that affect performance.
- D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:
 1. Quantities of outdoor, supply, return, and exhaust airflows.
 2. Water and steam flow rates.
 3. Duct, outlet, and inlet sizes.
 4. Pipe and valve sizes and locations.
 5. Terminal units.
 6. Balancing stations.
 7. Position of balancing devices.
- E. Air-Handling-Unit Test Reports: For air-handling units, include the following:
 1. Unit Data:
 - a. Unit identification.
 - b. Location.
 - c. Make and type.
 - d. Model number and unit size.
 - e. Manufacturer's serial number.
 - f. Unit arrangement and class.
 - g. Discharge arrangement.
 - h. Sheave make, size in inches, and bore.
 - i. Center-to-center dimensions of sheave and amount of adjustments in inches.
 - j. Number, make, and size of belts.
 - k. Number, type, and size of filters.

2. Motor Data:
 - a. Motor make, and frame type and size.
 - b. Horsepower and speed.
 - c. Volts, phase, and hertz.
 - d. Full-load amperage and service factor.
 - e. Sheave make, size in inches, and bore.
 - f. Center-to-center dimensions of sheave and amount of adjustments in inches.
3. Test Data (Indicated and Actual Values):
 - a. Total airflow rate in cfm.
 - b. Total system static pressure in inches wg.
 - c. Fan speed.
 - d. Inlet and discharge static pressure in inches wg.
 - e. For each filter bank, filter static-pressure differential in inches wg.
 - f. Preheat-coil static-pressure differential in inches wg.
 - g. Cooling-coil static-pressure differential in inches wg.
 - h. Heating-coil static-pressure differential in inches wg.
 - i. List for each internal component with pressure-drop, static-pressure differential in inches wg.
 - j. Outdoor airflow in cfm.
 - k. Return airflow in cfm.
 - l. Outdoor-air damper position.
 - m. Return-air damper position.
 - n. Vortex damper position.

F. Apparatus-Coil Test Reports:

1. Coil Data:
 - a. System identification.
 - b. Location.
 - c. Coil type.
 - d. Number of rows.
 - e. Fin spacing in fins per inch o.c.
 - f. Make and model number.
 - g. Face area in sq. ft.
 - h. Tube size in NPS.
 - i. Tube and fin materials.
 - j. Circuiting arrangement.
2. Test Data (Indicated and Actual Values):
 - a. Airflow rate in cfm.
 - b. Average face velocity in fpm.
 - c. Air pressure drop in inches wg.
 - d. Outdoor-air, wet- and dry-bulb temperatures in deg F.
 - e. Return-air, wet- and dry-bulb temperatures in deg F.
 - f. Entering-air, wet- and dry-bulb temperatures in deg F.
 - g. Leaving-air, wet- and dry-bulb temperatures in deg F.
 - h. Water flow rate in gpm.
 - i. Water pressure differential in feet of head or psig.
 - j. Entering-water temperature in deg F.
 - k. Leaving-water temperature in deg F.
 - l. Refrigerant expansion valve and refrigerant types.

- m. Refrigerant suction pressure in psig.
- n. Refrigerant suction temperature in deg F.
- o. Inlet steam pressure in psig.

G. Gas- and Oil-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:

1. Unit Data:

- a. System identification.
- b. Location.
- c. Make and type.
- d. Model number and unit size.
- e. Manufacturer's serial number.
- f. Fuel type in input data.
- g. Output capacity in Btu/h.
- h. Ignition type.
- i. Burner-control types.
- j. Motor horsepower and speed.
- k. Motor volts, phase, and hertz.
- l. Motor full-load amperage and service factor.
- m. Sheave make, size in inches, and bore.
- n. Center-to-center dimensions of sheave and amount of adjustments in inches.

2. Test Data (Indicated and Actual Values):

- a. Total airflow rate in cfm.
- b. Entering-air temperature in deg F.
- c. Leaving-air temperature in deg F.
- d. Air temperature differential in deg F.
- e. Entering-air static pressure in inches wg.
- f. Leaving-air static pressure in inches wg.
- g. Air static-pressure differential in inches wg.
- h. Low-fire fuel input in Btu/h.
- i. High-fire fuel input in Btu/h.
- j. Manifold pressure in psig.
- k. High-temperature-limit setting in deg F.
- l. Operating set point in Btu/h.
- m. Motor voltage at each connection.
- n. Motor amperage for each phase.
- o. Heating value of fuel in Btu/h.

H. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air-handling units, include the following:

1. Unit Data:

- a. System identification.
- b. Location.
- c. Coil identification.
- d. Capacity in Btu/h.
- e. Number of stages.
- f. Connected volts, phase, and hertz.
- g. Rated amperage.
- h. Airflow rate in cfm.
- i. Face area in sq. ft.

- j. Minimum face velocity in fpm.
- 2. Test Data (Indicated and Actual Values):
 - a. Heat output in Btu/h.
 - b. Airflow rate in cfm.
 - c. Air velocity in fpm.
 - d. Entering-air temperature in deg F.
 - e. Leaving-air temperature in deg F.
 - f. Voltage at each connection.
 - g. Amperage for each phase.
- I. Fan Test Reports: For supply, return, and exhaust fans, include the following:
 - 1. Fan Data:
 - a. System identification.
 - b. Location.
 - c. Make and type.
 - d. Model number and size.
 - e. Manufacturer's serial number.
 - f. Arrangement and class.
 - g. Sheave make, size in inches, and bore.
 - h. Center-to-center dimensions of sheave and amount of adjustments in inches.
 - 2. Motor Data:
 - a. Motor make, and frame type and size.
 - b. Horsepower and speed.
 - c. Volts, phase, and hertz.
 - d. Full-load amperage and service factor.
 - e. Sheave make, size in inches, and bore.
 - f. Center-to-center dimensions of sheave and amount of adjustments in inches.
 - g. Number, make, and size of belts.
 - 3. Test Data (Indicated and Actual Values):
 - a. Total airflow rate in cfm.
 - b. Total system static pressure in inches wg.
 - c. Fan speed.
 - d. Discharge static pressure in inches wg.
 - e. Suction static pressure in inches wg.
- J. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:
 - 1. Report Data:
 - a. System fan and air-handling-unit number.
 - b. Location and zone.
 - c. Traverse air temperature in deg F.
 - d. Duct static pressure in inches wg.
 - e. Duct size in inches.
 - f. Duct area in sq. ft.
 - g. Indicated airflow rate in cfm.

- h. Indicated velocity in fpm.
- i. Actual airflow rate in cfm.
- j. Actual average velocity in fpm.
- k. Barometric pressure in psig.

K. Air-Terminal-Device Reports:

1. Unit Data:

- a. System and air-handling unit identification.
- b. Location and zone.
- c. Apparatus used for test.
- d. Area served.
- e. Make.
- f. Number from system diagram.
- g. Type and model number.
- h. Size.
- i. Effective area in sq. ft.

2. Test Data (Indicated and Actual Values):

- a. Airflow rate in cfm.
- b. Air velocity in fpm.
- c. Preliminary airflow rate as needed in cfm.
- d. Preliminary velocity as needed in fpm.
- e. Final airflow rate in cfm.
- f. Final velocity in fpm.
- g. Space temperature in deg F.

L. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:

- a. System and air-handling-unit identification.
- b. Location and zone.
- c. Room or riser served.
- d. Coil make and size.
- e. Flowmeter type.

2. Test Data (Indicated and Actual Values):

- a. Airflow rate in cfm.
- b. Entering-water temperature in deg F.
- c. Leaving-water temperature in deg F.
- d. Water pressure drop in feet of head or psig.
- e. Entering-air temperature in deg F.
- f. Leaving-air temperature in deg F.

M. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves, and include the following:

1. Unit Data:

- a. Unit identification.
- b. Location.

- c. Service.
- d. Make and size.
- e. Model number and serial number.
- f. Water flow rate in gpm.
- g. Water pressure differential in feet of head or psig.
- h. Required net positive suction head in feet of head or psig.
- i. Pump speed.
- j. Impeller diameter in inches.
- k. Motor make and frame size.
- l. Motor horsepower and rpm.
- m. Voltage at each connection.
- n. Amperage for each phase.
- o. Full-load amperage and service factor.
- p. Seal type.

2. Test Data (Indicated and Actual Values):

- a. Static head in feet of head or psig.
- b. Pump shutoff pressure in feet of head or psig.
- c. Actual impeller size in inches.
- d. Full-open flow rate in gpm.
- e. Full-open pressure in feet of head or psig.
- f. Final discharge pressure in feet of head or psig.
- g. Final suction pressure in feet of head or psig.
- h. Final total pressure in feet of head or psig.
- i. Final water flow rate in gpm.
- j. Voltage at each connection.
- k. Amperage for each phase.

N. Instrument Calibration Reports:

1. Report Data:

- a. Instrument type and make.
- b. Serial number.
- c. Application.
- d. Dates of use.
- e. Dates of calibration.

3.25 VERIFICATION OF TAB REPORT

- A. The TAB specialist's test and balance engineer shall conduct the inspection in the presence of Architect Owner Construction Manager Commissioning Authority.
- B. Architect Owner Construction Manager Commissioning Authority shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to the lesser of either 10 (other) percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day (other).
- C. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
- D. If the number of "FAILED" measurements is greater than 10 20 (other) percent of the total measurements checked during the final inspection, the TAB shall be considered incomplete and shall be rejected.

- E. If recheck measurements find the number of failed measurements noncompliant with requirements indicated, proceed as follows:
 - 1. TAB specialists shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection. All changes shall be tracked to show changes made to previous report.
 - 2. If the second final inspection also fails, Owner may pursue others Contract options to complete TAB work.
- F. Prepare test and inspection reports.

3.26 ADDITIONAL TESTS

- A. Within 90 (other) days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.
- B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

END OF SECTION 230593

SECTION 230713 - DUCT INSULATION

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes insulating the following duct services:

1. Indoor, concealed supply and outdoor air.
2. Indoor, exposed supply and outdoor air.

B. Related Requirements:

1. Section 230716 "HVAC Equipment Insulation."
2. Section 230719 "HVAC Piping Insulation."
3. Section 233113 "Metal Ducts" for duct liners.

1.2 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory- and field-applied if any).

1.3 QUALITY ASSURANCE

- A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or craft training program, certified by the Department of Labor, Bureau of Apprenticeship and Training.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers are to be marked with the manufacturer's name, appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.5 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Coordinate clearance requirements with duct Installer for duct insulation application. Before preparing ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.
- C. Coordinate installation and testing of heat tracing.

1.6 SCHEDULING

- A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

- A. Comply with requirements in "Duct Insulation Schedule, General," "Indoor Duct and Plenum Insulation Schedule," and "Aboveground, Outdoor Duct and Plenum Insulation Schedule" articles for where insulating materials are to be applied.
- B. Products do not contain asbestos, lead, mercury, or mercury compounds.
- C. Products that come in contact with stainless steel have a leachable chloride content of less than 50 ppm when tested in accordance with ASTM C871.
- D. Insulation materials for use on austenitic stainless steel are qualified as acceptable in accordance with ASTM C795.
- E. Foam insulation materials do not use CFC or HCFC blowing agents in the manufacturing process.
- F. Flexible Elastomeric: Closed-cell or expanded-rubber materials; suitable for maximum use temperature between minus 70 deg F and 220 deg F. Comply with ASTM C534, Type II for sheet materials.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Aeroflex USA.
 - b. Armacell LLC.
 - c. K-Flex USA.
- G. Glass-Fiber Blanket: Glass fibers bonded with a thermosetting resin; suitable for maximum use temperature up to 450 deg F in accordance with ASTM C411. Comply with ASTM C553, Type II, and ASTM C1290, Type III with factory-applied FSK jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Certainteed; SAINT-GOBAIN.
 - b. Johns Manville; a Berkshire Hathaway company.
 - c. Knauf Insulation.
 - d. Manson Insulation Inc.
 - e. Owens Corning.
- H. Glass-Fiber Board Insulation: Glass fibers bonded with a thermosetting resin; suitable for maximum use temperature between 35 deg F and 250 deg F for jacketed and between 35 deg F and 450 deg F for unfaced in accordance with ASTM C411. Comply with ASTM C612, Type IA or Type IB. For duct and plenum applications, provide insulation with factory-applied FSK jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Certainteed; SAINT-GOBAIN.
 - b. Johns Manville; a Berkshire Hathaway company.
 - c. Knauf Insulation.
 - d. Manson Insulation Inc.
 - e. Owens Corning.

- I. Glass-Fiber, Pipe and Tank: Glass fibers bonded with a thermosetting resin; suitable for maximum use temperature between 35 deg F and 850 deg F, in accordance with ASTM C411. Comply with ASTM C1393.
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Certainteed; SAINT-GOBAIN.
 - b. Johns Manville; a Berkshire Hathaway company.
 - c. Knauf Insulation.
 - d. Manson Insulation Inc.
 - e. Owens Corning.
 2. Semirigid board material with factory-applied ASJ jacket.
 3. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

2.2 ADHESIVES

- A. Materials are compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.
- B. Glass-Fiber and Mineral Wool Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
- C. FSK Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.

2.3 MASTICS AND COATINGS

- A. Materials are compatible with insulation materials, jackets, and substrates.
- B. Vapor-Retarder Mastic, Water Based, Interior Use: Suitable for indoor use on below ambient services.
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 - c. Knauf Insulation.
 - d. Vimasco Corporation.
 2. Water-Vapor Permeance: Comply with ASTM C755, Section 7.2.2, Table 2, for insulation type and service conditions.
 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 4. Comply with MIL-PRF-19565C, Type II, for permeance requirements.
 5. Color: White.

2.4 LAGGING ADHESIVES

- A. Description: Comply with MIL-A-3316C, Class I, Grade A and are compatible with insulation materials, jackets, and substrates.
1. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over duct insulation.
 2. Service Temperature Range: 0 to plus 180 deg F.
 3. Color: White.

2.5 SEALANTS

- A. FSK and Metal Jacket Flashing Sealants:
1. Materials are compatible with insulation materials, jackets, and substrates.
 2. Fire- and water-resistant, flexible, elastomeric sealant.
 3. Service Temperature Range: Minus 40 to plus 250 deg F.
 4. Color: Aluminum.

2.6 FACTORY-APPLIED JACKETS

- A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
1. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C1136, Type II.

2.7 FIELD-APPLIED FABRIC-REINFORCING MESH

- A. Woven Glass-Fiber Mesh: Approximately 6 oz./sq. yd. with a thread count of 5 strands by 5 strands/sq. in. for covering ducts.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.

2.8 TAPES

- A. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C1136.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. 3M Industrial Adhesives and Tapes Division.
 - b. Avery Dennison Corporation, Specialty Tapes Division.
 - c. Knauf Insulation.
 2. Width: 3 inches.
 3. Thickness: 6.5 mils.
 4. Adhesion: 90 ounces force/inch in width.

5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

2.9 SECUREMENTS

A. Insulation Pins and Hangers:

1. Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- diameter shank, length to suit depth of insulation indicated.
2. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.
3. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:
 - a. Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.
 - b. Spindle: Copper- or zinc-coated, low-carbon steel , fully annealed, 0.106-inch- diameter shank, length to suit depth of insulation indicated.
 - c. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.
4. Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:
 - a. Baseplate: Perforated, nylon sheet, 0.030 inch thick by 1-1/2 inches in diameter.
 - b. Spindle: Nylon, 0.106-inch- diameter shank, length to suit depth of insulation indicated, up to 2-1/2 inches.
 - c. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.
5. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:
 - a. Baseplate: Galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.
 - b. Spindle: Copper- or zinc-coated, low-carbon steel , fully annealed, 0.106-inch- diameter shank, length to suit depth of insulation indicated.
 - c. Adhesive-backed base with a peel-off protective cover.
6. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- thick, galvanized-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.
 - a. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.
7. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

- B. Wire: 0.062-inch soft-annealed, galvanized steel.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
 - 1. Verify that systems to be insulated have been tested and are free of defects.
 - 2. Verify that surfaces to be insulated are clean and dry.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

3.3 GENERAL INSTALLATION REQUIREMENTS

- A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of ducts and fittings.
- B. Install insulation materials, vapor barriers or retarders, jackets, and thicknesses required for each item of duct system as specified in insulation system schedules.
- C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, compress, or otherwise damage insulation or jacket.
- D. Install insulation with longitudinal seams at top and bottom of horizontal runs.
- E. Install multiple layers of insulation with longitudinal and end seams staggered.
- F. Keep insulation materials dry during application and finishing. Replace insulation materials that get wet during storage or in the installation process before being properly covered and sealed in accordance with Contract Documents.
- G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- H. Install insulation with least number of joints practical.
- I. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
 - 1. Install insulation continuously through hangers and around anchor attachments.
 - 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.

3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
- J. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- K. Install insulation with factory-applied jackets as follows:
 1. Draw jacket tight and smooth, but not to the extent of creating wrinkles or areas of compression in the insulation.
 2. Cover circumferential joints with 3-inch- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
 3. Overlap jacket longitudinal seams at least 1-1/2 inches. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 4 inches o.c.
 - a. For below ambient services, apply vapor-barrier mastic over staples.
 4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
 5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.
- L. Cut insulation in a manner to avoid compressing insulation.
- M. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
- N. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

3.4 INSTALLATION OF FLEXIBLE ELASTOMERIC AND POLYOLEFIN INSULATION

- A. Comply with manufacturer's written installation instructions and ASTM C1710.
- B. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
- C. Square and Rectangular Ducts and Plenums:
 1. Provide 1/4 inch more per side for a tight, compression fit.
 2. Cut sheet insulation with the following dimensions:
 - a. Width of duct plus 1/4 inch, one piece.
 - b. Height of duct plus 1/4 inch, plus thickness of insulation, two pieces.
 - c. Width of duct plus 1/4 inch, plus two times the thickness of insulation, one piece.
 3. Insulate the bottom of the duct with the sheet from (a) above, then the sides with the two sheets from (b) above, and finally the top of the duct with the sheet from (c) above.
 4. Insulation without self-adhering backing:
 - a. Apply 100 percent coverage of manufacturer adhesive on the metal surface, then the insulation, except for the last 1/4 inch where sheets will butt together.
 - b. Roll sheet down into position.

- c. Press two sheets together under compression and apply adhesive at the butt joint to seal the two sheets together.
5. Insulation with self-adhering backing:
 - a. Peel back release paper in 6- to 8-inch increments and line up sheet.
 - b. Press firmly to activate adhesive.
 - c. Align material and continue to line up correctly, pressing firmly while slowly removing release paper.
 - d. Allow 1/4-inch overlap for compression at butt joints.
 - e. Apply adhesive at the butt joint to seal the two sheets together.
6. Insulate duct brackets following manufacturer's written installation instructions.

D. Circular Ducts:

1. Determine the circumference of the duct, using a strip of insulation the same thickness as to be used.
2. Cut the sheet to the required size.
3. Apply 100 percent coverage of manufacturer adhesive on the metal surface then the insulation.
4. Apply manufacturer adhesive to the cut surfaces along 100 percent of the longitudinal seam. Press together the seam at the ends and then the middle. Close the entire seam starting from the middle.

3.5 INSTALLATION OF GLASS-FIBER AND MINERAL-WOOL INSULATION

A. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

B. Comply with manufacturer's written installation instructions.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 50 percent coverage of duct and plenum surfaces.
2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
 - a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
 - b. On duct sides with dimensions larger than 18 inches, place pins 12 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
 - c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
 - d. Do not overcompress insulation during installation.
 - e. Impale insulation over pins and attach speed washers.
 - f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.
 - a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
 - b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation

face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.

5. Overlap unfaced blankets a minimum of 2 inches on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches o.c.
6. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
7. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

C. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 50 percent coverage of duct and plenum surfaces.
2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
 - a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
 - b. On duct sides with dimensions larger than 18 inches, space pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
 - c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
 - d. Do not overcompress insulation during installation.
 - e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.
 - a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
 - b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.
5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

3.6 FIELD-APPLIED JACKET INSTALLATION

- A. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.
1. Draw jacket smooth and tight to surface with 2-inch overlap at seams and joints.
 2. Embed glass cloth between two 0.062-inch- thick coats of lagging adhesive.
 3. Completely encapsulate insulation with coating, leaving no exposed insulation.
- B. Where FSK jackets are indicated, install as follows:
1. Draw jacket material smooth and tight.
 2. Install lap or joint strips with same material as jacket.
 3. Secure jacket to insulation with manufacturer's recommended adhesive.
 4. Install jacket with 1-1/2-inch laps at longitudinal seams and 3-inch- wide joint strips at end joints.
 5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.
- C. Where PVC jackets are indicated, install with 1-inch overlap at longitudinal seams and end joints; for horizontal applications, install with longitudinal seams along top and bottom of tanks and vessels. Seal with manufacturer's recommended adhesive.
1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.
- D. Where metal jackets are indicated, install with 2-inch overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless steel bands 12 inches o.c. and at end joints.

3.7 FINISHES

- A. Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."
1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
 - a. Finish Coat Material: Interior, flat, latex-emulsion size.
- B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.
- C. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.
- D. Do not field paint aluminum or stainless steel jackets.

3.8 DUCT INSULATION SCHEDULE, GENERAL

- A. Plenums and Ducts Requiring Insulation:
1. Indoor, concealed supply and outdoor air.

2. Indoor, exposed supply and outdoor air.

B. Items Not Insulated:

1. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
2. Factory-insulated flexible ducts.
3. Factory-insulated plenums and casings.
4. Flexible connectors.
5. Factory-insulated access panels and doors.

3.9 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Concealed, round and flat-oval, supply-air duct insulation is the following:

1. Glass-Fiber Blanket: 2 inches thick and 3 lb/cu. ft. nominal density.

B. Concealed, rectangular, supply-air duct insulation is the following:

1. Glass-Fiber Blanket: 2 inches thick and 3 lb/cu. ft. nominal density.

C. Exposed, round and flat-oval, supply-air duct insulation is one of the following:

1. Glass-Fiber Pipe and Tank: 2 inches thick.

D. Exposed, rectangular, supply-air duct insulation is one of the following:

1. Glass-Fiber Board: 2 inches thick and 3 lb/cu. ft. nominal density.

3.10 ABOVEGROUND, OUTDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Insulation materials and thicknesses are identified below. If more than one material is listed for a duct system, selection from materials listed is Contractor's option.

END OF SECTION 230713

SECTION 230716 - HVAC EQUIPMENT INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes insulating HVAC equipment that is not factory insulated.
- B. Related Sections:
 - 1. Section 230713 "Duct Insulation."
 - 2. Section 230719 "HVAC Piping Insulation."

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied if any).

1.4 QUALITY ASSURANCE

- A. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products in accordance with ASTM E84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.
 - 1. Insulation Installed Indoors: Flame-spread index of 25 or less and smoke-developed index of 50 or less.
- B. Insulation Installed Outdoors: Flame-spread index of 75 or less and smoke-developed index of 150 or less.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.6 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Coordinate clearance requirements with equipment Installer for equipment insulation application.

- C. Coordinate installation and testing of heat tracing.

1.7 SCHEDULING

- A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.
- B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products in accordance with ASTM E84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.
 - 1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
 - 2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

2.2 INSULATION MATERIALS

- A. Comply with requirements in "Breeching Insulation Schedule," "Indoor Equipment Insulation Schedule," and "Outdoor, Aboveground Equipment Insulation Schedule?" articles for where insulating materials shall be applied.
- B. Products shall not contain asbestos, lead, mercury, or mercury compounds.
- C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested in accordance with ASTM C871.
- D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable in accordance with ASTM C795.
- E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.
- F. Calcium Silicate: Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C533, Type I or Type II.
 - 1. Prefabricated Fitting Covers: Comply with ASTM C450 and ASTM C585 for dimensions used in preforming insulation to cover valves, elbows, tees, and flanges.
 - 2. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Johns Manville; a Berkshire Hathaway company.
- G. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Comply with ASTM C552.

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Owens Corning.
 2. Block Insulation: Type I.
 3. Special-Shaped Insulation: Type III.
 4. Board Insulation: Type IV.
 5. Factory-fabricate shapes in accordance with ASTM C450 and ASTM C585.
 6. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
- H. Flexible Elastomeric: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C534/C534M, Type II for sheet materials.
1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Aeroflex USA.
 - b. Armacell LLC.
 - c. K-Flex USA.
- I. Mineral-Fiber Blanket: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C553, Type II, and ASTM C1290, Type II, with factory-applied vinyl jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Certainteed; SAINT-GOBAIN.
 - b. Johns Manville; a Berkshire Hathaway company.
 - c. Knauf Insulation.
 - d. Manson Insulation Inc.
 - e. Owens Corning.
- J. Mineral-Fiber, Pipe and Tank: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C1393.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Certainteed; SAINT-GOBAIN.
 - b. Johns Manville; a Berkshire Hathaway company.
 - c. Knauf Insulation.
 - d. Manson Insulation Inc.
 - e. Owens Corning.
 2. Semirigid board material with factory-applied jacket.
 3. Nominal density is 2.5 lb/cu. ft. or more.
 4. Thermal conductivity (k-value) at 100 deg F is 0.29 Btu x in./h x sq. ft. x deg F or less.
 5. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
- K. Polyisocyanurate: Preformed, rigid cellular polyisocyanurate material intended for use as thermal insulation. Comply with ASTM C591.
1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Johns Manville; a Berkshire Hathaway company.

2. Type I or Type IV, except thermal conductivity (k-value) shall not exceed 0.19 Btu x in./h x sq. ft. x deg F at 75 deg F after 180 days of aging.
3. Flame-spread index shall be 25 or less and smoke-developed index shall be 50 or less for thicknesses of up to 1 inch as tested in accordance with ASTM E84.
4. Fabricate shapes in accordance with ASTM C450 and ASTM C585.
5. Factory-Applied Jacket: Requirements are specified in "Factory-Applied Jackets" Article.
 - a. Equipment Applications: None.

2.3 INSULATING CEMENTS

A. Mineral-Fiber Insulating Cement: Comply with ASTM C195.

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Ramco Insulation, Inc.

2.4 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Flexible Elastomeric and Polyolefin Adhesive: Solvent-based adhesive.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Aeroflex USA.
 - b. Armacell LLC.
 - c. K-Flex USA.
2. Flame-spread index shall be 25 or less and smoke-developed index shall be 50 or less as tested in accordance with ASTM E84.
3. Wet Flash Point: Below 0 deg F
4. Service Temperature Range: 40 to 200 deg F.
5. Color: Black.

C. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

D. ASJ Adhesive and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.

2.5 MASTICS AND COATINGS

A. Materials shall be compatible with insulation materials, jackets, and substrates.

B. Vapor-Retarder Mastic, Water Based: Suitable for indoor and outdoor use on below-ambient services.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 - c. Knauf Insulation.

- d. Vimasco Corporation.
 - 2. Water-Vapor Permeance: Comply with ASTM E96/E96M or ASTM F1249.
 - 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 - 4. Comply with MIL-PRF-19565C, Type II, for permeance requirements.
 - 5. Color: White.
- C. Vapor-Retarder Mastic, Solvent Based, Outdoor Use: Suitable for outdoor use on below-ambient services.
- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 - 2. Water-Vapor Permeance: Comply with ASTM E96/E96M or ASTM F1249.
 - 3. Service Temperature Range: Minus 50 to plus 220 deg F.
 - 4. Color: White.
- D. Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.
- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 - c. Knauf Insulation.
 - d. Vimasco Corporation.
 - 2. Water-Vapor Permeance: ASTM E96/E96M, greater than 1.0 perm at manufacturer's recommended dry film thickness.
 - 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 - 4. Color: White.

2.6 LAGGING ADHESIVES

- A. Adhesives shall comply with MIL-A-3316C, Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.
- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 - c. Vimasco Corporation.
 - 2. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over equipment insulation.
 - 3. Service Temperature Range: 0 to plus 180 deg F.
 - 4. Color: White.

2.7 SEALANTS

- A. Materials shall be as recommended by the insulation manufacturer and shall be compatible with insulation materials, jackets, and substrates.

B. Joint Sealants:

1. Permanently flexible, elastomeric sealant.
2. Service Temperature Range: Minus 100 to plus 300 deg F.
3. Color: White or gray.

C. FSK and Metal Jacket Flashing Sealants:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
2. Fire- and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: Minus 40 to plus 250 deg F.
4. Color: Aluminum.

D. ASJ Flashing Sealants and Vinyl, PVDC, and PVC Jacket Flashing Sealants:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
2. Fire- and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: Minus 40 to plus 250 deg F.
4. Color: White.

2.8 FIELD-APPLIED FABRIC-REINFORCING MESH

- A. Woven Glass-Fiber Fabric: Approximately 4 oz./sq. yd. with a thread count of 5 strands by 5 strands/sq. in. for covering equipment.

2.9 FIELD-APPLIED CLOTHS

- A. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of 8 oz./sq. yd.

2.10 FIELD-APPLIED JACKETS

- A. Field-applied jackets shall comply with ASTM C1136, Type I, unless otherwise indicated.
- B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.
- C. Self-Adhesive Outdoor Jacket: 60-mil- thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with aluminum-foil facing.
1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Polyguard Products, Inc.

2.11 TAPES

- A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C1136.
 - 1. Width: 3 inches.
 - 2. Thickness: 11.5 mils.
 - 3. Adhesion: 90 ounces force/inch in width.
 - 4. Elongation: 2 percent.
 - 5. Tensile Strength: 40 lbf/inch in width.
 - 6. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.
- B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C1136.
 - 1. Width: 3 inches.
 - 2. Thickness: 6.5 mils.
 - 3. Adhesion: 90 ounces force/inch in width.
 - 4. Elongation: 2 percent.
 - 5. Tensile Strength: 40 lbf/inch in width.
 - 6. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
 - 1. Verify that systems and equipment to be insulated have been tested and are free of defects.
 - 2. Verify that surfaces to be insulated are clean and dry.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
- B. Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:
 - 1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer 5 mils thick and an epoxy finish 5 mils thick if operating in a temperature range of between 140 and 300 deg F. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
 - 2. Carbon Steel: Coat carbon steel operating at a service temperature of between 32 and 300 deg F with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
- C. Coordinate insulation installation with the tradesman installing heat tracing. Comply with requirements for heat tracing that apply to insulation.

- D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless steel surfaces, use demineralized water.

3.3 GENERAL INSTALLATION REQUIREMENTS

- A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of equipment.
- B. Install insulation materials, forms, vapor barriers or retarders, and jackets, of thicknesses required for each item of equipment, as specified in insulation system schedules.
- C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.
- D. Install insulation with longitudinal seams at top and bottom of horizontal runs.
- E. Install multiple layers of insulation with longitudinal and end seams staggered.
- F. Keep insulation materials dry during storage, application, and finishing. Replace insulation materials that get wet.
- G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- H. Install insulation with least number of joints practical.
- I. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
 - 1. Install insulation continuously through hangers and around anchor attachments.
 - 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends attached to structure with vapor-barrier mastic.
 - 3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
 - 4. Cover inserts with jacket material matching adjacent insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.
- J. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- K. Install insulation with factory-applied jackets as follows:
 - 1. Draw jacket tight and smooth.
 - 2. Cover circumferential joints with 3-inch- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward-clinching staples along both edges of strip, spaced 4 inches o.c.
 - 3. Overlap jacket longitudinal seams at least 1-1/2 inches. Clean and dry surface to receive self-sealing lap. Staple laps with outward-clinching staples along edge at 2 inches o.c.
 - a. For below-ambient services, apply vapor-barrier mastic over staples.
 - 4. Cover joints and seams with tape, in accordance with insulation material manufacturer's written instructions, to maintain vapor seal.
 - 5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints.

- L. Cut insulation in a manner to avoid compressing insulation more than 25 percent of its nominal thickness.
- M. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
- N. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches in similar fashion to butt joints.
- O. For above-ambient services, do not install insulation to the following:
 - 1. Vibration-control devices.
 - 2. Testing agency labels and stamps.
 - 3. Nameplates and data plates.
 - 4. Manholes.
 - 5. Handholes.
 - 6. Cleanouts.

3.4 INSTALLATION OF EQUIPMENT, TANK, AND VESSEL INSULATION

- A. Mineral-Fiber, Pipe and Tank Insulation Installation for Tanks and Vessels: Secure insulation with adhesive, anchor pins, and speed washers.
 - 1. Apply adhesives in accordance with manufacturer's recommended coverage rates per unit area, for 50 percent coverage of tank and vessel surfaces.
 - 2. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.
 - 3. Protect exposed corners with secured corner angles.
 - 4. Install adhesively attached or self-sticking insulation hangers and speed washers on sides of tanks and vessels as follows:
 - a. Do not weld anchor pins to ASME-labeled pressure vessels.
 - b. Select insulation hangers and adhesive that are compatible with service temperature and with substrate.
 - c. On tanks and vessels, maximum anchor-pin spacing is 3 inches from insulation end joints and 16 inches o.c. in both directions.
 - d. Do not over-compress insulation during installation.
 - e. Cut and miter insulation segments to fit curved sides and domed heads of tanks and vessels.
 - f. Impale insulation over anchor pins, and attach speed washers.
 - g. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
 - 5. Secure each layer of insulation with stainless steel or aluminum bands. Select band material compatible with insulation materials.
 - 6. Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch prestressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment approximately 6 inches from each end. Install wire or cable between two circumferential girdles 12 inches o.c. Install a wire ring around each end and around outer periphery of center openings, and stretch prestressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional circumferential girdles along the body of equipment or tank at a minimum spacing of 48 inches o.c. Use this network for securing insulation with tie wire or bands.
 - 7. Stagger joints between insulation layers at least 3 inches.

8. Install insulation in removable segments on equipment access doors, manholes, handholes, and other elements that require frequent removal for service and inspection.
9. Bevel and seal insulation ends around manholes, handholes, ASME stamps, and nameplates.
10. For equipment with surface temperatures below ambient, apply mastic to open ends, joints, seams, breaks, and punctures in insulation.

B. Flexible Elastomeric Thermal Insulation Installation for Tanks and Vessels: Install insulation over entire surface of tanks and vessels.

1. Apply 100 percent coverage of adhesive to surface with manufacturer's recommended adhesive.
2. Seal longitudinal seams and end joints.

C. Insulation Installation on Pumps:

1. Fabricate metal boxes lined with insulation. Fit boxes around pumps and coincide box joints with splits in pump casings. Fabricate joints with outward bolted flanges. Bolt flanges on 6-inch centers, starting at corners. Install 3/8-inch- diameter fasteners with wing nuts. Alternatively, secure the box sections together using a field-adjustable latching mechanism.
2. Fabricate boxes from aluminum or stainless steel, at least 0.040 inch thick.
3. For below-ambient services, install a vapor barrier at seams, joints, and penetrations. Seal between flanges with replaceable gasket material to form a vapor barrier.

3.5 INSTALLATION OF CALCIUM SILICATE INSULATION

A. Insulation Installation on Boiler Breechings:

1. Secure single-layer insulation with stainless steel bands at 12-inch intervals, and tighten bands without deforming insulation material.
2. Install two-layer insulation with joints tightly butted and staggered at least 3 inches. Secure inner layer with wire spaced at 12-inch intervals. Secure outer layer with stainless steel bands at 12-inch intervals.
3. On exposed applications without metal jacket, finish insulation surface with a skim coat of mineral-fiber, hydraulic-setting cement. When cement is dry, apply flood coat of lagging adhesive and press on one layer of glass cloth. Overlap edges at least 1 inch. Apply finish coat of lagging adhesive over glass cloth. Thin finish coat to achieve smooth, uniform finish.

3.6 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

- A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.7 FIELD-APPLIED JACKET INSTALLATION

- A. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.

1. Draw jacket smooth and tight to surface with 2-inch overlap at seams and joints.
2. Embed glass cloth between two 0.062-inch- thick coats of lagging adhesive.
3. Completely encapsulate insulation with coating, leaving no exposed insulation.

- B. Where FSK jackets are indicated, install as follows:
1. Draw jacket material smooth and tight.
 2. Install lap or joint strips with same material as jacket.
 3. Secure jacket to insulation with manufacturer's recommended adhesive.
 4. Install jacket with 1-1/2-inch laps at longitudinal seams and 3-inch- wide joint strips at end joints.
 5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.
- C. Where PVC jackets are indicated, install with 1-inch overlap at longitudinal seams and end joints; for horizontal applications, install with longitudinal seams along top and bottom of tanks and vessels. Seal with manufacturer's recommended adhesive.
1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.
- D. Where metal jackets are indicated, install with 2-inch overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless steel bands 12 inches o.c. and at end joints.
- E. Where PVDC jackets are indicated, install as follows:
1. Jacket can be wrapped in cigarette fashion along length of roll for insulation systems with an outer circumference of 33-1/2 inches or less. 33-1/2-inch- circumference limit allows for 2-inch- overlap seal. Using the length of roll allows for longer sections of jacket to be installed at one time. Use adhesive on the lap seal. Visually inspect lap seal for "fishmouthing," and use PVDC tape along lap seal to secure joint.
 2. Repair holes or tears in PVDC jacket by placing PVDC tape over the hole or tear and wrapping a minimum of 1-1/4 circumferences to avoid damage to tape edges.

3.8 FINISHES

- A. Equipment Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."
1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
 - a. Finish Coat Material: Interior, flat, latex-emulsion size.
- B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.
- C. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.
- D. Do not field paint aluminum or stainless-steel jackets.

3.9 FIELD QUALITY CONTROL

- A. Perform tests and inspections.

- B. Tests and Inspections: Inspect field-insulated equipment, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to one location(s) for each type of equipment defined in "Indoor Equipment Insulation Schedule" and "Outdoor, Aboveground Equipment Insulation Schedule" articles. For large equipment, remove only a portion adequate to determine compliance.
- C. All insulation applications will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.10 EQUIPMENT INSULATION SCHEDULE, GENERAL

- A. Insulation conductivity and thickness per pipe size shall comply with schedules in this Section or with requirements of authorities having jurisdiction, whichever is more stringent.
- B. Acceptable insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials is Contractor's option.

3.11 INDOOR EQUIPMENT INSULATION SCHEDULE

- A. Insulate indoor and outdoor equipment that is not factory insulated.
- B. Chilled-water pump insulation shall be the following:
 - 1. Cellular Glass: 3 inches thick.
- C. Chilled-water expansion/compression tank insulation shall be the following:
 - 1. Flexible Elastomeric: 1 inch thick.
- D. Chilled-water air-separator insulation shall be the following:
 - 1. Flexible Elastomeric: 1 inch thick.
- E. Thermal storage tank (brine, water, ice) insulation shall be the following:
 - 1. Cellular Glass: 4 inches thick.

END OF SECTION 230716

SECTION 230719 - HVAC PIPING INSULATION

PART 1 - GENERAL

1.1 SUMMARY

- A. Section includes insulation for HVAC piping systems.
- B. Related Requirements:
 - 1. Section 230713 "Duct Insulation" for duct insulation.
 - 2. Section 230716 "HVAC Equipment Insulation" for equipment insulation.
 - 3. Section 232113.13 "Underground Hydronic Piping" loose-fill pipe insulation in underground piping outside the building.
 - 4. Section 232213.13 "Underground Steam and Condensate Heating Piping" for steam and condensate piping for steam-type tank heaters.

1.2 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied, if any).

1.3 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation system materials are to be delivered to the Project site in unopened containers. The packaging is to include name of manufacturer, fabricator, type, description, and size , as well as ASTM standard designation, and maximum use temperature.

1.4 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Coordinate clearance requirements with piping Installer for piping insulation application. Before preparing piping Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.
- C. Coordinate installation and testing of heat tracing.

1.5 SCHEDULING

- A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products in accordance with ASTM E84 by a testing agency acceptable to authorities having jurisdiction. Factory label insulation, jacket materials, adhesive, mastic, tapes, and cement material containers with appropriate markings of applicable testing agency.
 - 1. All Insulation Installed Indoors and Outdoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.

2.2 INSULATION MATERIALS

- A. Comply with requirements in "Piping Insulation Schedule, General," "Indoor Piping Insulation Schedule," "Outdoor, Aboveground Piping Insulation Schedule," and "Outdoor, Underground Piping Insulation Schedule" articles for where insulating materials are applied.
- B. Products do not contain asbestos, lead, mercury, or mercury compounds.
- C. Products that come into contact with stainless steel have a leachable chloride content of less than 50 ppm when tested in accordance with ASTM C871.
- D. Insulation materials for use on austenitic stainless steel are qualified as acceptable in accordance with ASTM C795.
- E. Foam insulation materials do not use CFC or HCFC blowing agents in the manufacturing process.
- F. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Comply with ASTM C552.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Owens Corning.
 - 2. Preformed Pipe Insulation with Jacket: Type II, Class 2, with factory-applied ASJ-SSL jacket.
 - 3. Fabricated shapes in accordance with ASTM C450, ASTM C585, and ASTM C1639.
 - 4. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
- G. Flexible Elastomeric: Closed-cell, or expanded-rubber materials; suitable for maximum use temperature between minus 70 deg F and 220 deg F. Comply with ASTM C534/C534M, Type I, for tubular materials, Type II for sheet materials.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Aeroflex USA.
 - b. Armacell LLC.
 - c. K-Flex USA.

- H. Glass-Fiber, Preformed Pipe: Glass fibers bonded with a thermosetting resin; suitable for maximum use temperature up to 850 deg F in accordance with ASTM C411. Comply with ASTM C547.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Johns Manville; a Berkshire Hathaway company.
 - b. Knauf Insulation.
 - c. Manson Insulation Inc.
 - d. Owens Corning.
 - 2. Preformed Pipe Insulation: Type I, Grade A with factory-applied ASJ-SSL.
 - 3. Fabricated shapes in accordance with ASTM C450 and ASTM C585.
 - 4. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
- I. Glass-Fiber, Pipe and Tank: Glass fibers bonded with a thermosetting resin; suitable for maximum use temperature between 35 deg F and 850 deg F, in accordance with ASTM C411. Comply with ASTM C1393.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Certainteed; SAINT-GOBAIN.
 - b. Johns Manville; a Berkshire Hathaway company.
 - c. Knauf Insulation.
 - d. Manson Insulation Inc.
 - e. Owens Corning.
 - 2. Semirigid board material with factory-applied FSK jacket.
 - 3. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

2.3 INSULATING CEMENTS

- A. Glass-Fiber and Mineral Wool Insulating Cement: Comply with ASTM C195.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Ramco Insulation, Inc.
- B. Glass-Fiber and Mineral Wool Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C449.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Ramco Insulation, Inc.

2.4 ADHESIVES

- A. Materials are compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

- B. Cellular-Glass Adhesive: Two-component, thermosetting urethane adhesive containing no flammable solvents, with a service temperature range of minus 100 to plus 200 deg F.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Foster Brand; H. B. Fuller Construction Products.
- C. Phenolic and Polyisocyanurate Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 deg F.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
- D. Flexible Elastomeric and Polyolefin Adhesive: Solvent-based adhesive.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Aeroflex USA.
 - b. Armacell LLC.
 - c. K-Flex USA.
 - 2. Flame-spread index is 25 or less and smoke-developed index is 50 or less as tested in accordance with ASTM E84.
 - 3. Wet Flash Point: Below 0 deg F.
 - 4. Service Temperature Range: 40 to 200 deg F.
 - 5. Color: Black.
- E. Glass-Fiber and Mineral Wool Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
- F. ASJ Adhesive and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A, for bonding insulation jacket lap seams and joints.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
- G. PVC Jacket Adhesive: Compatible with PVC jacket.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Johns Manville; a Berkshire Hathaway company.
 - b. Proto Corporation.
 - c. Speedline Corporation.
 - d. The Dow Chemical Company.

2.5 MASTICS AND COATINGS

- A. Materials are compatible with insulation materials, jackets, and substrates.
- B. Vapor-Retarder Mastic, Water Based: Suitable for indoor use on below-ambient services.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 - c. Knauf Insulation.
 - d. Vimasco Corporation.
 - 2. Water-Vapor Permeance: Comply with ASTM E96/E96M or ASTM F1249.
 - 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 - 4. Comply with MIL-PRF-19565C, Type II, for permeance requirements.
 - 5. Color: White.
- C. Vapor-Retarder Mastic, Solvent Based, Outdoor Use: Suitable for outdoor use on below-ambient services.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 - 2. Water-Vapor Permeance: Comply with ASTM E96/E96M or ASTM F1249.
 - 3. Service Temperature Range: Minus 50 to plus 220 deg F.
 - 4. Color: White.
- D. Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 - c. Knauf Insulation.
 - d. Vimasco Corporation.
 - 2. Water-Vapor Permeance: ASTM E96/E96M, greater than 1.0 perm at manufacturer's recommended dry film thickness.
 - 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 - 4. Color: White.

2.6 LAGGING ADHESIVES

- A. Adhesives comply with MIL-A-3316C, Class I, Grade A, and are compatible with insulation materials, jackets, and substrates.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 - c. Vimasco Corporation.

2. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over pipe insulation.
3. Service Temperature Range: 0 to plus 180 deg F.
4. Color: White.

2.7 SEALANTS

- A. Materials are as recommended by the insulation manufacturer and are compatible with insulation materials, jackets, and substrates.
- B. Joint Sealants:
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 - c. Owens Corning.
 2. Permanently flexible, elastomeric sealant.
 - a. Service Temperature Range: Minus 100 to plus 300 deg F.
 - b. Color: White or gray.
- C. ASJ Flashing Sealants and PVDC and PVC Jacket Flashing Sealants:
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Childers Brand; H. B. Fuller Construction Products.
 - b. Foster Brand; H. B. Fuller Construction Products.
 2. Fire- and water-resistant, flexible, elastomeric sealant.
 3. Service Temperature Range: Minus 40 to plus 250 deg F.
 4. Color: White.

2.8 FACTORY-APPLIED JACKETS

- A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
 1. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C1136, Type I.

2.9 FIELD-APPLIED JACKETS

- A. Field-applied jackets comply with ASTM C1136, Type I, unless otherwise indicated.

- B. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Airex Manufacturing Inc.
 - b. Johns Manville; a Berkshire Hathaway company.
 - c. Proto Corporation.
 - d. Speedline Corporation.
 2. Adhesive: As recommended by jacket material manufacturer.
 3. Color: White.
 4. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.
 - a. Shapes: 45- and 90-degree, short- and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.
- C. Metal Jacket:
1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Johns Manville; a Berkshire Hathaway company.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
1. Verify that systems to be insulated have been tested and are free of defects.
 2. Verify that surfaces to be insulated are clean and dry.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
- B. Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:
1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer 5 mils thick and an epoxy finish 5 mils thick if operating in a temperature range between 140 and 300 deg F. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
 2. Carbon Steel: Coat carbon steel operating at a service temperature of between 32 and 300 deg F with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.

- C. Coordinate insulation installation with the tradesman installing heat tracing. Comply with requirements for heat tracing that apply to insulation.
- D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless steel surfaces, use demineralized water.

3.3 GENERAL INSTALLATION REQUIREMENTS

- A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping, including fittings, valves, and specialties.
- B. Install insulation materials, forms, vapor barriers or retarders, jackets, and of thicknesses required for each item of pipe system, as specified in insulation system schedules.
- C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, compress, or otherwise damage insulation or jacket.
- D. Install insulation with longitudinal seams at top and bottom (12 o'clock and 6 o'clock positions) of horizontal runs.
- E. Install multiple layers of insulation with longitudinal and end seams staggered.
- F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.
- G. Keep insulation materials dry during storage, application, and finishing. Replace insulation materials that get wet during storage or in the installation process before being properly covered and sealed in accordance with the Contract Documents.
- H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- I. Install insulation with least number of joints practical.
- J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
 - 1. Install insulation continuously through hangers and around anchor attachments.
 - 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends attached to structure with vapor-barrier mastic.
 - 3. Install insert materials and insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
 - 4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.
- K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- L. Install insulation with factory-applied jackets as follows:
 - 1. Draw jacket tight and smooth, but not to the extent of creating wrinkles or areas of compression in the insulation.
 - 2. Cover circumferential joints with 3-inch- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward-clinching staples along both edges of strip, spaced 4 inches o.c.

3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward-clinching staples along edge at 4 inches o.c.
 4. For below-ambient services, apply vapor-barrier mastic over staples.
 5. Cover joints and seams with tape, in accordance with insulation material manufacturer's written instructions, to maintain vapor seal.
 6. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.
- M. Cut insulation in a manner to avoid compressing insulation.
- N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
- O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches in similar fashion to butt joints.
- P. For above-ambient services, do not install insulation to the following:
1. Vibration-control devices.
 2. Testing agency labels and stamps.
 3. Nameplates and data plates.

3.4 PENETRATIONS

- A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.
1. Seal penetrations with flashing sealant.
 2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
 3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
 4. Seal jacket to roof flashing with flashing sealant.
- B. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.
1. Seal penetrations with flashing sealant.
 2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
 3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
 4. Seal jacket to wall flashing with flashing sealant.
- C. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.
- D. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions.
1. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping and fire-resistive joint sealers.

E. Insulation Installation at Floor Penetrations:

1. Pipe: Install insulation continuously through floor penetrations.
2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.5 GENERAL PIPE INSULATION INSTALLATION

A. Requirements in this article generally apply to all insulation materials, except where more specific requirements are specified in various pipe insulation material installation articles below.

B. Insulation Installation on Fittings, Valves, Strainers, Flanges, Mechanical Couplings, and Unions:

1. Install insulation over fittings, valves, strainers, flanges, mechanical couplings, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.
2. Insulate pipe elbows using prefabricated fitting insulation made from same material and density as that of adjacent pipe insulation. Each piece is butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
3. Insulate tee fittings with prefabricated fitting insulation of same material and thickness as that used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
4. Insulate valves using prefabricated fitting insulation of same material, density, and thickness as that used for adjacent pipe. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
5. Insulate strainers using prefabricated fitting insulation of same material, density, and thickness as that used for adjacent pipe. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers, so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.
6. Insulate flanges, mechanical couplings, and unions using a section of oversized preformed pipe insulation to fit. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Stencil or label the outside insulation jacket of each union with the word "union" matching size and color of pipe labels.
7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
8. For services not specified to receive a field-applied jacket, except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing, using PVC tape.

C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

D. Install removable insulation covers at locations indicated. Installation conforms to the following:

1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as that of adjoining pipe insulation.

2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union at least 2 times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless steel or aluminum bands. Select band material compatible with insulation and jacket.
3. Construct removable valve insulation covers in same manner as for flanges, except divide the two-part section on the vertical center line of valve body.
4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.
5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.6 INSTALLATION OF CELLULAR-GLASS INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with wire or bands, and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with jackets on above-ambient services, secure laps with outward-clinched staples at 6 inches o.c.
4. For insulation with jackets on below-ambient services, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive, as recommended by insulation material manufacturer, and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install prefabricated pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of cellular-glass block insulation of same thickness as that of pipe insulation. Where voids are difficult to fill with block insulation, fill the voids with a fibrous insulation material suitable for the specific operating temperature.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install prefabricated sections of same material as that of straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
2. When preformed sections of insulation are not available, install mitered or routed sections of cellular-glass insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install prefabricated sections of cellular-glass insulation to valve body.
2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.

3.7 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

- A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
- B. Insulation Installation on Pipe Flanges:
 - 1. Install pipe insulation to outer diameter of pipe flange.
 - 2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
 - 3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as that of pipe insulation.
 - 4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
- C. Insulation Installation on Pipe Fittings and Elbows:
 - 1. Install sections of pipe insulation and miter if required in accordance with manufacturer's written instructions.
 - 2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
- D. Insulation Installation on Valves and Pipe Specialties:
 - 1. Install prefabricated valve covers manufactured of same material as that of pipe insulation when available.
 - 2. When prefabricated valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
 - 3. Install insulation to flanges as specified for flange insulation application.
 - 4. Secure insulation to valves and specialties, and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.8 INSTALLATION OF GLASS-FIBER AND MINERAL WOOL INSULATION

- A. Insulation Installation on Straight Pipes and Tubes:
 - 1. Secure each layer of preformed pipe insulation to pipe with wire or bands, and tighten bands without deforming insulation materials.
 - 2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
 - 3. For insulation with jackets on above-ambient surfaces, secure laps with outward-clinched staples at 6 inches o.c.
 - 4. For insulation with jackets on below-ambient surfaces, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive, as recommended by insulation material manufacturer, and seal with vapor-barrier mastic and flashing sealant.
- B. Insulation Installation on Pipe Flanges:
 - 1. Install prefabricated pipe insulation to outer diameter of pipe flange.
 - 2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.

3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with glass-fiber or mineral-wool blanket insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install prefabricated sections of same material as that of straight segments of pipe insulation when available.
2. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install prefabricated sections of same material as that of straight segments of pipe insulation when available.
2. When prefabricated sections are not available, install fabricated sections of pipe insulation to valve body.
3. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
4. Install insulation to flanges as specified for flange insulation application.

3.9 INSTALLATION OF FIELD-APPLIED JACKETS

A. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.

1. Draw jacket smooth and tight to surface with 2-inch overlap at seams and joints.
2. Embed glass cloth between two 0.062-inch- thick coats of lagging adhesive.
3. Completely encapsulate insulation with coating, leaving no exposed insulation.

B. Where PVC jackets are indicated and for horizontal applications, install with 1-inch overlap at longitudinal seams and end joints. Seal with manufacturer's recommended adhesive.

1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.

C. Where metal jackets are indicated, install with 2-inch overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless steel bands 12 inches o.c. and at end joints.

D. Where PVDC jackets are indicated, install as follows:

1. Apply three separate wraps of filament tape per insulation section to secure pipe insulation to pipe prior to installation of PVDC jacket.
2. Wrap presized jackets around individual pipe insulation sections, with one end overlapping the previously installed sheet. Install presized jacket with an approximate overlap at butt joint of 2 inches over the previous section. Adhere lap seal using adhesive or SSL, and then apply 1-1/4 circumferences of appropriate PVDC tape around overlapped butt joint.
3. Continuous jacket can be spiral-wrapped around a length of pipe insulation. Apply adhesive or PVDC tape at overlapped spiral edge. When electing to use adhesives, refer to manufacturer's written instructions for application of adhesives along this spiral edge to maintain a permanent bond.

4. Jacket can be wrapped in cigarette fashion along length of roll for insulation systems with an outer circumference of 33-1/2 inches or less. The 33-1/2-inch- circumference limit allows for 2-inch-overlap seal. Using the length of roll allows for longer sections of jacket to be installed at one time. Use adhesive on the lap seal. Visually inspect lap seal for "fishmouthing," and use PVDC tape along lap seal to secure joint.
5. Repair holes or tears in PVDC jacket by placing PVDC tape over the hole or tear and wrapping a minimum of 1-1/4 circumferences to avoid damage to tape edges.

3.10 FINISHES

- A. Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."
 1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
 - a. Finish Coat Material: Interior, flat, latex-emulsion size.
- B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.
- C. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.
- D. Do not field paint aluminum or stainless steel jackets.

3.11 PIPING INSULATION SCHEDULE, GENERAL

- A. Insulation conductivity and thickness per pipe size comply with schedules in this Section or with requirements of authorities having jurisdiction, whichever is more stringent.
- B. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.
- C. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:
 1. Underground piping.
 2. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

3.12 INDOOR PIPING INSULATION SCHEDULE

- A. Condensate and Equipment Drain Water below 60 Deg F:
 1. All Pipe Sizes: Insulation is the following:
 - a. Flexible Elastomeric: 1 1/2 inch thick.

- B. Chilled Water and Brine, Above 40 Deg F:
 - 1. NPS 12 and Smaller: Insulation is one of the following:
 - a. Cellular Glass: 1-1/2 inches thick.
- C. Refrigerant Suction and Hot-Gas Piping:
 - 1. All Pipe Sizes: Insulation is the following:
 - a. Flexible Elastomeric: 1 1/2 inch thick.

3.13 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

- A. Chilled Water and Brine:
 - 1. All Pipe Sizes: Insulation is one of the following:
 - a. Cellular Glass: 2 inches thick.
- B. Heating-Hot-Water Supply and Return, 200 Deg F and Below:
 - 1. All Pipe Sizes: Insulation is one of the following:
 - a. Glass-Fiber, Preformed Pipe Insulation, Type I: 2 inches thick.
- C. Refrigerant Suction and Hot-Gas Piping:
 - 1. All Pipe Sizes: Insulation is the following:
 - a. Flexible Elastomeric: 1 1/2 inch thick.

3.14 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE

- A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
- B. If more than one material is listed, selection from materials listed is Contractor's option.
- C. Piping, Exposed:
 - 1. Aluminum, Smooth : 0.020 inch thick.

END OF SECTION 230719

SECTION 230800 - COMMISSIONING OF HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes Cx process requirements for the following HVAC systems, assemblies, and equipment:

1. Heat generation systems.
2. Cooling generation systems.
3. Central-station air-handling systems.
4. Air, steam, and hydronic distribution systems.
5. Heating and cooling terminal and unitary equipment.
6. HVAC controls.
7. TAB verification.

- B. Related Requirements:

1. Section 019113 "General Commissioning Requirements" for general Cx process requirements and CxA responsibilities.
2. For construction checklists, comply with requirements in various Division 23 Sections specifying HVAC systems, system components, equipment, and products.

1.3 DEFINITIONS

- A. BAS: Building automation system.
- B. Cx: Commissioning, as defined in Section 019113 "General Commissioning Requirements."
- C. CxA: Commissioning Authority, as defined in Section 019113 "General Commissioning Requirements."
- D. IgCC: International Green Construction Code.
- E. "Systems," "Assemblies," "Subsystems," "Equipment," and "Components": Where these terms are used together or separately, they mean "as-built" systems, assemblies, subsystems, equipment, and components.
- F. TAB: Testing, adjusting, and balancing.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For BAS and HVAC testing technician.

B. Construction Checklists:

1. Draft Cx plan, including draft construction checklists to be prepared by CxA under Section 019113 "General Commissioning Requirements." Div. 23 Subcontractor is to review Construction Checklist in accordance with requirements in Section 019113 "General Commissioning Requirements" and ASHRAE 202 and to resolve any issues with the CxA.

C. Test Equipment and Instruments: For all test equipment and instruments to be used in conducting Cx tests by Div. 23 Subcontractor, provide the following:

1. Equipment/instrument identification number.
2. Planned Cx application or use.
3. Manufacturer, make, model, and serial number.
4. Calibration history, including certificates from agencies that calibrate the equipment and instrumentation.
5. Equipment manufacturers' proprietary instrumentation and tools. For each instrument or tool, identify the following:
 - a. Instrument or tool identification number.
 - b. Equipment schedule designation of equipment for which the instrument or tool is required.
 - c. Manufacturer, make, model, and serial number.
 - d. Calibration history, including certificates from agencies that calibrate the instrument or tool, where appropriate.

1.5 QUALITY ASSURANCE

A. BAS Testing Technician Qualifications: Technicians performing BAS Construction Checklist verification tests, Construction Checklist verification test demonstrations, Cx tests, and Cx test demonstrations are to have the following minimum qualifications:

1. Journey level or equivalent skill level with knowledge of BAS, HVAC, electrical concepts, and building operations.
2. Minimum three years' (other) experience installing, servicing, and operating systems manufactured by approved manufacturer.
3. International Society of Automation (ISA)-Certified Control Systems Technician (CCST) Level I.

B. HVAC Testing Technician Qualifications: Technicians to perform HVAC Construction Checklist verification tests, Construction Checklist verification test demonstrations, Cx tests, and Cx test demonstrations shall have the following minimum qualifications:

1. Journey level or equivalent skill level; vocational school four-year-program graduate or an Associate's degree in mechanical systems, air conditioning, or similar field. Degree may be offset by three years' experience in servicing mechanical systems in the HVAC industry. Generally, required knowledge includes HVAC systems, electrical concepts, building operations, and application and use of tools and instrumentation to measure performance of HVAC equipment, assemblies, and systems.
2. Minimum three years' (other) experience that is to include installing, servicing, and operating systems manufactured by approved manufacturer.

C. Testing Equipment and Instrumentation Quality and Calibration:

1. Capable of testing and measuring performance within the specified acceptance criteria.
2. Be calibrated at manufacturer's recommended intervals with current calibration tags permanently affixed to the instrument being used.

3. Be maintained in good repair and operating condition throughout duration of use on Project.
4. Be recalibrated/repared if dropped or damaged in any way since last calibrated.

D. Proprietary Test Instrumentation and Tools:

1. Equipment Manufacturer's Proprietary Instrumentation and Tools: For installed equipment included in the Cx process, test instrumentation and tools manufactured or prescribed by equipment manufacturer to service, calibrate, adjust, repair, or otherwise work on its equipment or required as a condition of equipment warranty, shall comply with the following:
 - a. Be calibrated by manufacturer with current calibration tags permanently affixed.
 - b. Include a separate list of proprietary test instrumentation and tools in operation and maintenance manuals.
2. HVAC proprietary test instrumentation and tools become property of Owner at the time of Substantial Completion.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 Cx PROCESS:

- A. Perform Cx process in accordance with Section 019113 "General Commissioning Requirements" for BAS and HVAC and in accordance with the following:
 1. IgCC, which requires compliance with ASHRAE 202.
 2. ASHRAE 202.
 3. Commissioning standards acceptable to the authority having jurisdiction.

3.2 CONSTRUCTION CHECKLISTS

- A. Preliminary detailed construction checklists are to be prepared under Section 019113 "General Commissioning Requirements" for each BAS and HVAC system, assembly, subsystem, equipment, and component required to be commissioned, as detailed in IgCC and ASHRAE 202. Contractor performs the following:
 1. Review BAS and HVAC preliminary construction checklists and provide written comments on checklist items where appropriate.
 2. Return preliminary Construction Checklist with review comments within 10 (other) days of receipt.
 3. When review comments have been resolved, the CxA will provide final construction checklists marked "Approved for Use, (date)."
 4. Use only construction checklists marked "Approved for Use, (date)" When performing tests. Mark construction checklists in the appropriate place as indicated Project events are completed, and provide pertinent details and other information.
- B. Prepare preliminary detailed construction checklists for each BAS and HVAC system, assembly, subsystem, equipment, and component required to be commissioned, as detailed in IgCC and ASHRAE 202.
 1. Submit preliminary construction checklists to CxA and Designer for review.

2. When review comments have been resolved, the CxA will provide final construction checklists marked "Approved for Use, (date)."
 3. Use only construction checklists, marked "Approved for Use, (date)" when performing tests. Mark construction checklists in the appropriate place, as indicated Project events are completed and provide pertinent details and other information.
- C. Systems required to be commissioned under IgCC:
1. Heating, ventilating, air-conditioning, and refrigeration systems (mechanical and/or passive) and associated controls.
 2. Air-curtain systems.
 3. Water-pumping and -mixing systems over 5 hp and purification systems.
 4. Renewable energy systems and energy storage systems.
 5. Energy and building management and demand-control systems.
- D. Additional systems required to be commissioned:
1. Energy supply systems, including the following:
 - a. Fuel-oil supply.
 - b. Fuel gas supply.
 - c. Central-plant steam supply.
 - d. Central-plant hot-water supply.
 - e. Solar-energy supply.
 - f. Renewable energy systems.
 - g. Energy storage systems.
 - h. Demand-control systems.
 2. Heat generation systems, including the following:
 - a. Boilers.
 - b. Furnaces.
 - c. Fuel-fired unit heaters.
 - d. Auxiliary equipment.
 3. Cooling generation systems, including the following:
 - a. Water chillers.
 - b. Cooling towers.
 - c. Direct-expansion refrigeration systems.
 4. Air-handling systems, including the following:
 - a. Supply, return, and exhaust air fans, motors, and drives.
 - b. Automatic and gravity dampers.
 - c. Heating and cooling devices.
 - d. Humidification and dehumidification devices.
 - e. Air filters.
 - f. Hangers and supports.
 - g. Interlock between air-handling system and fire/smoke alarm system.
 5. Air duct systems, including the following:
 - a. Duct systems.

- b. Air-duct accessories, including volume dampers, fire and smoke dampers, turning vanes, sound attenuators, and flexible connectors.
 - c. Duct-mounted access doors and panels.
 - d. Hangers and supports.
- 6. Air curtain systems.
 - a. Supply air fans and motors.
 - b. Heating and cooling devices.
- 7. Steam and hydronic distribution systems, including the following:
 - a. Steam distribution piping systems.
 - b. Condensate piping systems, including condensate pumps and all accessories.
 - c. Hydronic piping systems and all accessories.
 - d. Pumps and all accessories.
 - e. Sleeves and sleeve seals.
 - f. Meters and gauges.
 - g. General-duty and specialty valves.
 - h. Hangers and supports
- 8. Refrigerant piping, including the following:
 - a. Refrigerant piping, fittings, and specialties.
 - b. Refrigerant charge.
 - c. Sleeves and sleeve seals.
 - d. Meters and gauges.
 - e. General-duty and specialty valves.
 - f. Hangers and supports.
- 9. Smoke-control systems, including the following:
 - a. Exhaust and makeup fans, motors, and drives.
 - b. Exhaust and makeup air distribution systems.
 - c. Smoke dampers.
 - d. Smoke detectors.
 - e. Fire and smoke alarm system interface.
- 10. Heating and cooling terminal and unitary equipment, including the following:
 - a. Unit ventilators.
 - b. Unit heaters.
 - c. Fan-coil units.
 - d. Finned-tube radiation.
 - e. Electric heating.
 - f. Unitary heating and cooling equipment.
- 11. Controls and instrumentation, including the following:
 - a. Energy monitoring and recording system.
 - b. Controllers and sensors.
 - c. Automatic control valves, dampers, and actuators.
 - d. Control interface with fans, pumps, dampers, and other equipment and systems.
 - e. Demand-control systems.

12. TAB Verification:
 - a. Airflow.
 - b. Water flow.
 - c. Space pressurization.
13. Documentation:
 - a. Mechanical systems manuals.
 - b. Documentation of required commissioning.
14. Mechanical insulation, including the following:
 - a. Duct and plenum insulation.
 - b. HVAC piping insulation.

3.3 Cx TESTING PREPARATION

- A. Certify that HVAC systems, subsystems, and equipment have been installed, calibrated, and started and that they are operating in accordance with the Contract Documents and approved submittals.
- B. Certify that HVAC instrumentation and control systems have been completed and calibrated, point-to-point checkout has been successfully completed, and systems are operating in accordance with their design sequence of operation, Contract Documents, and approved submittals. Certify that all sensors are operating within specified accuracy and all systems are set to and maintaining set points as required by the design documents.
- C. Certify that TAB procedures have been completed and that TAB reports have been submitted, discrepancies corrected, and corrective work approved.
- D. Set systems, subsystems, and equipment into operating mode to be tested in accordance with approved test procedures (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).

3.4 Cx TEST CONDITIONS

- A. Perform tests using design conditions, whenever possible.
 1. Simulated conditions may, with approval of Architect, be imposed using an artificial load when it is impractical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by CxA, and document simulated conditions and methods of simulation. After tests, return configurations and settings to normal operating conditions.
 2. Cx test procedures may direct that set points be altered when simulating conditions is impractical.
 3. Cx test procedures may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are impractical.
- B. If tests cannot be completed because of a deficiency outside the scope of the HVAC system, document the deficiency and report it to Architect. After deficiencies are resolved, reschedule tests.
- C. If seasonal testing is specified, complete appropriate initial performance tests and documentation, and schedule seasonal tests.

3.5 Cx TESTS COMMON TO HVAC SYSTEMS

- A. Measure capacities and effectiveness of systems, assemblies, subsystems, equipment, and components, including operational and control functions, to verify compliance with acceptance criteria.
- B. Test systems, assemblies, subsystems, equipment, and components for operating modes, interlocks, control responses, responses to abnormal or emergency conditions, and response in accordance with acceptance criteria.
- C. Coordinate schedule with, and perform Cx activities at the direction of, CxA.
- D. Comply with Construction Checklist requirements, including material verification, installation checks, startup, and performance test requirements specified in Division 23 Sections specifying HVAC systems and equipment.
- E. Provide technicians, instrumentation, tools, and equipment to perform and document the following:
 - 1. Cx Construction Checklist verification tests.
 - 2. Cx Construction Checklist verification test demonstrations.

3.6 TAB VERIFICATION

- A. Prerequisites: Completion of "Examination" Article requirements and correction of deficiencies, as specified in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
- B. Completion of "Preparation" Article requirements for preparation of a TAB plan that includes strategies and step-by-step procedures, and system-readiness checks and reports, as specified in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
- C. Scope: HVAC air systems and hydronic piping systems.
- D. Purpose: Differential flow relationships intended to maintain air and water pressurization differentials between the various areas of Project.
- E. Conditions of the Test:
 - 1. Cx Test Demonstration Sampling Rate: As specified in "Inspections" Article in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
 - 2. Systems operating in full heating mode with minimum outside-air volume.
 - 3. Systems operating in full cooling mode with minimum outside-air volume.
 - 4. For measurements at air-handling units with economizer controls; systems operating in economizer mode with 100 percent outside air.
- F. Acceptance Criteria:
 - 1. Under all conditions, rechecked measurements comply with "Inspections" Article in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
 - 2. Additionally, no rechecked measurement shall differ from measurements documented in the final report by more than the tolerances allowed.
 - 3. Under all conditions, where the Contract Documents indicate a differential in airflow between supply and exhaust and/or return in a space, the differential relationship shall be maintained.

3.7 HEATING CONTROL SYSTEM Cx TESTS

A. Heating-Water Supply Temperature Control:

1. Prerequisites: Installation verification of the following:
 - a. Startup of boiler (other) steam to hot-water converter (other) (other).
 - b. Startup of heating-water pump(s) (other).
 - c. TAB of heating-water flow and pressure.
 - d. Input Device: Heating-water supply temperature; thermostat thermistor temperature sensor resistance temperature sensor (other).
 - e. Output Device: Control valve (other).
 - f. Display the following at the operator's workstation:
 - 1) Heating-water supply temperature.
 - 2) Heating-water supply temperature set point.
 - 3) Control-valve position.
2. Scope: Heating-water system.
3. Purpose: Control of heating-water supply temperature at input device (other).
4. Conditions of the Test:
 - a. Minimum heating-water flow.
 - b. Midrange Heating-Water Flow: 50 to 60 (other) percent of maximum.
 - c. Maximum heating-water flow.
5. Acceptance Criteria: Under all conditions, heating-water supply temperature is within plus or minus 2.0 deg F (other) of set point.

B. Heating-Water Supply Temperature Reset:

1. Prerequisites: Installation verification of the following:
 - a. Startup of boiler (other) steam to hot-water converter (other) (other).
 - b. Startup of heating-water pump(s) (other).
 - c. TAB of heating-water flow and pressure.
 - d. Input Device: Heating-water supply temperature; thermostat thermistor temperature sensor resistance temperature sensor (other).
 - e. Input Device: Outdoor-air temperature; electric, outdoor-air-reset controller outdoor-air sensor.
 - f. Output Device: Control valve (other).
 - g. Display the following at the operator's workstation:
 - 1) Outdoor-air temperature.
 - 2) Heating-water supply temperature.
 - 3) Heating-water supply temperature set point.
 - 4) Control-valve position.
2. Scope: Heating-water system.
3. Purpose: Control of heating-water supply temperature at heating-water supply temperature input device (other) in response to variable outdoor-air temperature input; electric, outdoor-air-reset controller outdoor-air sensor (other).
4. Conditions of the Test: Outdoor-air temperature input value may be overridden for this test.
 - a. Low Temperature: Outdoor-air temperature between minus 30 and 0 deg F (other).
 - b. Midrange Temperature: Outdoor-air temperature between 30 and 45 deg F (other).

- c. High Temperature: Outdoor-air temperature above 65 deg F (other).
- 5. Acceptance Criteria: Heating-water supply temperature resets in straight-line relationship with outdoor-air temperature for the following reset schedule. Under all conditions, heating-water supply temperature is within 2.0 deg F (other) of set point.
 - a. 195 deg F (other) heating water when outdoor-air temperature is minus 30 deg F (other).
 - b. 130 deg F (other) heating water when outdoor-air temperature is 65 deg F (other).
 - c. Under all conditions, heating-water supply temperature is within plus or minus 2.0 deg F (other) of set point.
- C. Control Primary Circulating Pump(s):
 - 1. Prerequisites: Installation verification of the following:
 - a. Startup of heating-water pump(s) (other).
 - b. Input Device: Outdoor-air temperature; electric, outdoor-air-reset controller outdoor-air sensor (other).
 - c. Output Device: Heating-water pump; starter DDC system command to starter (other) relay.
 - d. Display the following at the operator's workstation:
 - 1) Outdoor-air temperature.
 - 2) Operating status of primary circulating pump(s).
 - 2. Scope: Heating-water pump(s) (other) and associated controls.
 - 3. Purpose: On-off control of heating-water pump(s) in response to variable outdoor-air temperature input; electric, outdoor-air-reset controller outdoor-air sensor (other).
 - 4. Conditions of the Test:
 - a. High Temperature: Outdoor-air temperature above 65 deg F (other).
 - b. Low Temperature: Outdoor-air temperature below 65 deg F.
 - 5. Acceptance Criteria:
 - a. High Temperature: Pump(s) are off when outside-air temperature is above 65 deg F (other).
 - b. Low Temperature: Pump(s) are on when outside-air temperature is below 65 deg F (other).

3.8 CHILLER SYSTEM Cx TESTS

- A. Start-and-Stop Condenser-Water Pump(s):
 - 1. Prerequisites: Installation verification of the following:
 - a. Startup of condenser-water pump(s) (other).
 - b. Startup of cooling tower (other).
 - c. Input Device: Water pressure transducer (other).
 - d. Input Device: Space thermostat DDC system outdoor-air temperature.
 - e. Input Device: Time clock DDC system time schedule (other).
 - f. Output Device: Hard wired through motor starter; DDC system binary output (other).
 - g. Output Device: Time clock Binary output (other).
 - h. Display the following at the operator's workstation:
 - 1) Low-level cooling-tower sump alarm.
 - 2) Outdoor-air temperature.

- 3) Cooling (software) demand indication.
- 4) Time and time schedule.
- 5) Condenser-water pump(s) on-off status.
- 6) Condenser-water pump(s) on-off indication.
- 7) Condenser-water flow indication.

2. Scope:

- a. Condenser-water system, including condenser-water pump(s), cooling towers, and associated controls.

3. Purpose:

- a. Condenser-water pump(s) lockout.
- b. Condenser-water pump(s) start.
- c. Condenser-water pump(s) shutdown.
- d. Low-level cooling-tower sump alarm.
- e. Condenser-water pump(s) time-of-day schedule.

4. Conditions of the Test:

- a. Verify Lockout: Start with condenser-water pump enable-input devices in the "disable" state to prevent pump start. One by one, place the enable-input devices in the "enable" state, and then return each to the "disable" state before placing the next enable-input device to the "enable" state.
- b. Verify Start: Start with condenser-water pump enable-input devices in the "disable" state to prevent pump start. One by one, place the enable-input devices in the "enable" state.
- c. Verify Shutdown: Place all enable-input devices in the "enable" state to allow the pump(s) to start. One by one, place the enable-input devices in the "disable" state, and then return each to the "enable" state before placing the next enable-input device to the "disable" state.
- d. Verify Schedule: Compare condenser-water pump start-and-stop schedule times with Owner-approved time-of-day schedule.

5. Acceptance Criteria:

- a. Lockout: No single enable-input device starts the pump(s) when released to the "enable" state.
- b. Start: Condenser-water pump(s) start when, and only when, all enable-input devices are in the "enable" state.
- c. Shutdown: Each enable-input device stops the condenser-water pump(s) when placed in the "disable" state, regardless of the state of other enable-input devices.
- d. Schedule: Condenser-water pump start-and-stop schedule times agree with Owner-approved time-of-day schedule.

B. Start-and-Stop Chilled-Water Pump(s):

1. Prerequisites: Installation verification of the following:

- a. Startup of chilled-water pump(s) (other).
- b. Startup of condenser-water pump(s) (other).
- c. Startup of cooling tower (other).
- d. Input Device: Flow switch in condenser-water circuit (other).
- e. Output Device: Starter DDC system command to starter (other) relay.

- f. Display one of the following at the operator's workstation:
 - 1) Chilled-water flow indication.
 - 2) Condenser-water flow indication.
 - 3) Chilled-water pump(s) on-off status.
 - 4) Chilled-water pump(s) on-off indication.
 - 2. Scope: Chilled-water system, including chilled-water pump(s), associated controls, and condenser-water system controls.
 - 3. Purpose:
 - a. Chilled-water pump(s) start.
 - b. Chilled-water pump(s) shutdown.
 - 4. Conditions of the Test:
 - a. Verify Start: Start with chilled-water pump enable-input device in the "disable" state to prevent pump start. Place the enable-input device in the "enable" state.
 - b. Verify Shutdown: Start with the enable-input device in the "enable" state to allow the pump(s) to run. Then place the enable-input device in the "disable" state.
 - 5. Acceptance Criteria:
 - a. Start: Chilled-water pump(s) start when, and only when, the enable-input device is in the "enable" state.
 - b. Shutdown: The enable-input device stops the chilled-water pump(s) when placed in the "disable" state.
- C. Start-and-Stop Cooling-Tower Fans(s):
- 1. Prerequisites: Installation verification of the following:
 - a. Input Device: Flow switch in condenser-water circuit (other).
 - b. Output Device: Starter DDC system command to starter (other) relay.
 - c. Display:
 - 1) Condenser-water flow indication.
 - 2) Cooling-tower fan(s) on-off indication.
 - 2. Scope: Condenser-water system, including cooling tower, condenser-water pump(s), and associated controls.
 - 3. Purpose:
 - a. Cooling-tower fan(s) start.
 - b. Cooling-tower fan(s) shutdown.
 - 4. Conditions of the Test:
 - a. Verify Start: Start with cooling-tower fan enable-input device in the "disable" state to prevent fan(s) start. Place the enable-input device in the "enable" state.
 - b. Verify Shutdown: Start with the enable-input device in the "enable" state to allow the fan(s) to run. Then place the enable-input device in the "disable" state.

5. Acceptance Criteria:
 - a. Start: Chilled-water pump(s) start when, and only when, the enable-input device is in the "enable" state.
 - b. Shutdown: The enable-input device stops the chilled-water pump(s) when placed in the "disable" state.

D. Alternative Chiller(s):

1. Prerequisites: Installation verification of the following:
 - a. Input Device: Electric alternator DDC system software (other).
 - b. Output Device: Chiller DDC system command to chiller (other) terminal strip.
 - c. Display:
 - 1) Chiller(s) on-off indication.
 - 2) Chiller failure alarm.
2. Scope:
 - a. Chilled-water system and associated controls.
 - b. Condenser-water system and associated controls.
3. Purpose:
 - a. Lead-lag rotation of chillers.
 - b. Replacement of failed chiller in rotation.
 - c. Adding and dropping chillers as follows: (other).
 - d. Replacement of failed chiller in add/drop sequence.
 - e. Chiller failure alarm initiation.
4. Conditions of the Test:
 - a. Lead-Lag Rotation - Chiller Start: Create a number of chilled-water system start-stop cycles equal to the number of chillers plus one.
 - b. Lead-Lag Rotation - Lead Chiller Fail: Disable the lead chiller while it is running.
 - c. Lead-Lag Rotation - Lag Chiller Fail: Disable a lag chiller while it is running.
 - d. Lead-Lag Rotation - Chiller Start Fail: Disable a chiller while it is in standby mode. Initiate a lead-lag rotation call for the disabled chiller to start.
 - e. Add/Drop Sequence - Increasing Demand: Increase chilled-water demand incrementally to observe the corresponding addition of chillers. Increase demand gradually as the load approaches the set point for adding the next chiller, to permit observation of the actual load at the time the next chiller is enabled.
 - f. Add/Drop Sequence - Decreasing Demand: Decrease chilled-water demand incrementally to observe the corresponding dropping of chillers. Decrease demand gradually as the load approaches the set point for dropping the next chiller, to permit observation of the actual load at the time the next chiller is disabled.
5. Acceptance Criteria:
 - a. Lead-Lag Rotation - Chiller Start: On each chilled-water system start event, the other next chiller in rotation starts as the lead chiller, and the previous lead chiller, is designated as the last-lag chiller.
 - b. Lead-Lag Rotation - Lead Chiller Fail: When the lead chiller fails, the other next chiller in rotation starts as the lead chiller, and a chiller failure alarm, is initiated for the failed chiller.

- c. Lead-Lag Rotation - Lag Chiller Fail: When the lag chiller fails, the next chiller in rotation starts as the lead chiller, and a chiller failure alarm is initiated for the failed chiller.
- d. Lead-Lag Rotation - Chiller Start Fail: When a chiller fails to start, the next chiller in rotation starts in its place, and a chiller failure alarm is initiated for the failed chiller.
- e. Add/Drop Sequence - Increasing Demand: Chillers are added at the specified load set point, plus or minus 5 (other) percent. Chilled-water supply temperature remains stable within plus or minus 2.0 deg F (other) of set point.
- f. Add/Drop Sequence - Decreasing Demand: Chillers are dropped at the specified load set point, plus or minus 5 (other) percent. Chilled-water supply temperature remains stable within plus or minus 2.0 deg F (other) of set point.
- g. Add/Drop Sequence - Operating Chiller Fail: When an operating chiller fails, the next chiller in sequence starts and a chiller failure alarm is initiated for the failed chiller.
- h. Add/Drop Sequence - Chiller Start Fail: When a chiller fails to start, the next chiller in sequence starts in its place and a chiller failure alarm is initiated for the failed chiller.

3.9 TERMINAL UNIT EQUIPMENT Cx TESTS

A. VAV Terminal Air Units with Coils:

- 1. Prerequisites: Installation verification of the following:
 - a. Occupancy Input Device: Occupancy sensor.
 - b. Occupancy Output Device: DDC system binary output.
 - c. Room Temperature Input Device: Room thermostat Electronic temperature sensor.
 - d. Room Temperature Output Device: Pneumatic Electronic damper actuators and control-valve operators.
 - e. Display the following at the operator's workstation:
 - 1) Room/area served.
 - 2) Room occupied/unoccupied.
 - 3) Room temperature indication.
 - 4) Room temperature set point.
 - 5) Room temperature set point, occupied.
 - 6) Room temperature set point, unoccupied.
 - 7) Air-damper position as percentage open.
 - 8) Control-valve position as percentage open.
- 2. Scope: VAV terminal air units with hydronic steam coils in supply-air systems, and associated controls.
- 3. Purpose:
 - a. Occupancy-dependent room temperature set-point reset.
 - b. Room temperature control.
- 4. Conditions of the Test:
 - a. Cx Test Demonstration Sampling Rate: 10 (other) percent of each model/size unit.
 - b. Temperature Control - Occupied: Start with the room unoccupied. Occupy the room and observe the change to occupied status. Observe temperature control until room temperature is stable at occupied set point, plus or minus 1.0 deg F (other).
 - c. Temperature Control - Unoccupied: Start with the room occupied. Vacate the room and observe the change to unoccupied status. Observe temperature control until room temperature is stable at unoccupied set point, plus or minus 1.0 deg F (other).

5. Acceptance Criteria:
 - a. Temperature Control - Occupied:
 - 1) Control system status changes from "occupied" to "unoccupied" after the specified time.
 - 2) Room temperature is stable at occupied set point, plus or minus 1.0 deg F within 10 (other) minutes of occupancy. Room temperature does not overshoot or undershoot set point by more than 2.0 deg F (other) during transition.
 - b. Temperature Control - Unoccupied:
 - 1) Control system status changes from "unoccupied" to "occupied" immediately after five minutes of continuous occupancy.
 - 2) Room temperature is stable at unoccupied set point, plus or minus 1.0 deg F (other) within 30 (other) minutes of occupancy.

3.10 AIR-HANDLING SYSTEM Cx TESTS

A. Supply Fan(s) Variable-Volume Control:

1. Prerequisites: Installation verification of the following:
 - a. Volume-Control Input Device: Static-pressure transmitter Differential-pressure switch sensing supply-duct static pressure referenced to conditioned-space static pressure.
 - b. Volume-Control Output Device: Receiver controller DDC system analog output DDC system analog output to digital-to-pneumatic transducer to modulating damper actuator. Set inlet guide vanes to minimum closed position when fan is stopped.
 - c. Volume-Control Input Device: Static-pressure transmitter Differential-pressure switch sensing supply-duct static pressure referenced to conditioned-space static pressure.
 - d. Volume-Control Output Device: Receiver controller DDC system analog output to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
 - e. High-Pressure Input Device: Static-pressure transmitter sensing supply-duct static pressure referenced to static pressure outside the duct.
 - f. High-Pressure Output Device: Receiver controller DDC system binary output to alarm panel motor starter.
 - g. Display the following at the operator's workstation:
 - 1) Supply-fan-discharge static-pressure indication.
 - 2) Supply-fan-discharge static-pressure set point.
 - 3) Supply-fan airflow rate.
 - 4) Supply-fan inlet vane position speed.
2. Scope: VAV supply fan units and associated controls.
3. Purpose:
 - a. Supply-air discharge static pressure control.
 - b. Response to excess supply-air discharge static pressure condition.
4. Conditions of the Test:
 - a. Minimum supply-air flow.
 - b. Midrange Supply-Air Flow: 50 to 60 (other) percent of maximum.
 - c. Maximum supply-air flow.

- d. Excess supply-air discharge static pressure.
- 5. Acceptance Criteria:
 - a. At all supply-air flow rates, and during changes in supply-air flow, discharge air static pressure is at set point plus or minus 2 (other) percent.
 - b. Fan stops and an alarm is initiated at the operator's workstation when supply-air discharge static pressure is at the excess static pressure, plus or minus 2 (other) percent.
- B. Air-Handler Mixed-Air Control:
 - 1. Prerequisites: Installation verification of the following:
 - a. Minimum Position Input Device: Time clock DDC system time schedule.
 - b. Output Device: Receiver controller DDC system analog output DDC system analog output to digital-to-pneumatic transducer to modulating damper actuator(s).
 - c. Heating Reset Input Device: Room thermostat DDC system software.
 - d. Supply Mixed-Air Temperature Input Device: Duct-mounted thermostat Electronic temperature sensor.
 - e. Cooling Reset Input Device: Outdoor- and return-air, duct-mounted thermostats electronic temperature sensors.
 - f. Display the following at the operator's workstation:
 - 1) Mixed-air-temperature indication.
 - 2) Mixed-air-temperature set point.
 - 3) Mixed-air damper position.
 - 2. Scope: Air handler with mixed-air control and associated controls.
 - 3. Purpose:
 - a. Occupied time control.
 - b. Minimum damper position control.
 - c. Heating reset control.
 - d. Supply Mixed-air temperature control.
 - e. Cooling reset control.
 - f. Unoccupied time control.
 - 4. Conditions of the Test:
 - a. Occupied Time Control: Start in unoccupied schedule. Advance to occupied schedule time.
 - b. Minimum Damper Position Control: Command system to mode in which minimum damper position is required.
 - c. Heating Reset Control: Create a call for heating.
 - d. Supply Mixed -Air Temperature Control: Override supply mixed -air temperature set point to a value 2.0 deg F (other) above current supply mixed-air temperature.
 - e. Cooling Reset Control: Override outdoor-air temperature to a value that exceeds return-air temperature enthalpy to a value that exceeds return-air enthalpy.
 - f. Unoccupied Time Control: Advance to unoccupied schedule time.
 - g. Control Data Trend Log: Set up a data trend log of the following input device values and output device commands. Record data at hourly (other) intervals. Submit trend data for 24-hour (other) periods in which natural conditions require heating reset control, supply mixed-air temperature control, and cooling reset control.
 - 1) Minimum position input device.
 - 2) Heating reset input device.

- 3) Supply Mixed-air temperature input device.
 - 4) Cooling reset input device.
5. Acceptance Criteria:
- a. Occupied Time Control: Mixed-air control is active in occupied mode.
 - b. Minimum Damper Position Control: Controller opens minimum outdoor-air dampers positions outdoor-air dampers to minimum position.
 - c. Heating Reset Control: Controller closes minimum outdoor-air dampers sets outdoor-air dampers to minimum position.
 - d. Supply Mixed -Air Temperature Control: Controller modulates outdoor-, return-, and relief-air dampers to maintain temporary supply mixed -air temperature set point, plus or minus 1.0 deg F (other).
 - e. Cooling Reset Control: Controller sets outdoor-air dampers to minimum position when outdoor-air temperature exceeds return-air temperature enthalpy exceeds return-air enthalpy.
 - f. Unoccupied Time Control: Controller positions outdoor- and relief-air dampers closed and return-air dampers open.
 - g. Control Data Trend Log: Data verify control in accordance with sequence of control.

END OF SECTION 230800

SECTION 230923 - DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. DDC system for monitoring and controlling of HVAC systems.
 - 2. Delivery of selected control devices to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.
- B. Related Requirements:
- C. Section 230923.13 "Energy Meters" for thermal and electric power energy meters that connect to DDC systems.
 - 1. Section 230923.17 "Level Instruments" for liquid-level switches, sensors, and transmitters that connect to DDC systems.
 - 2. Section 230923.22 "Position Instruments" for limit switches that connect to DDC systems.
 - 3. Section 230923.33 "Vibration Instruments" for vibration instruments that connect to DDC systems.
 - 4. Section 230923.43 "Weather Stations" for weather stations that connect to DDC systems.
 - 5. Section 230993.11 "Sequence of Operations for HVAC DDC" for control sequences in DDC systems.
 - 6. Communications Cabling:
 - a. Section 260523 "Control-Voltage Electrical Power Cables" for balanced twisted pair communications cable.
 - b. Section 271513 "Communications Copper Horizontal Cabling" for balanced twisted pair communications cable.
 - c. Section 271523 "Communications Optical Fiber Horizontal Cabling" for optical fiber communications cable.
 - 7. Raceways:
 - a. Section 260533 "Raceways and Boxes for Electrical Systems" for raceways for low-voltage control cable.
 - b. Section 270528 "Pathways for Communications Systems" for raceways for balanced twisted pair cabling and optical fiber cable.
 - 8. Section 260553 "Identification for Electrical Systems" for identification requirements for electrical components.
 - 9. Section 270553 "Identification for Communications Systems" for identification requirements for communications components.

1.3 DEFINITIONS

- A. Algorithm: A logical procedure for solving a recurrent mathematical problem. A prescribed set of well-defined rules or processes for solving a problem in a finite number of steps.
- B. Analog: A continuously varying signal value, such as current, flow, pressure, or temperature.
- C. BACnet Specific Definitions:
 - 1. BACnet: Building Automation Control Network Protocol, ASHRAE 135. A communications protocol allowing devices to communicate data over and services over a network.
 - 2. BACnet Interoperability Building Blocks (BIBBs): BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBs are combined to build the BACnet functional requirements for a device.
 - 3. BACnet/IP: Defines and allows using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP subnetworks that share the same BACnet network number.
 - 4. BACnet Testing Laboratories (BTL): Organization responsible for testing products for compliance with ASHRAE 135, operated under direction of BACnet International.
 - 5. PICS (Protocol Implementation Conformance Statement): Written document that identifies the particular options specified by BACnet that are implemented in a device.
- D. Binary: Two-state signal where a high signal level represents ON" or "OPEN" condition and a low signal level represents "OFF" or "CLOSED" condition. "Digital" is sometimes used interchangeably with "Binary" to indicate a two-state signal.
- E. Controller: Generic term for any standalone, microprocessor-based, digital controller residing on a network, used for local or global control. Three types of controllers are indicated: Network Controller, Programmable Application Controller, and Application-Specific Controller.
- F. Control System Integrator: An entity that assists in expansion of existing enterprise system and support of additional operator interfaces to I/O being added to existing enterprise system.
- G. COV: Changes of value.
- H. DDC System Provider: Authorized representative of, and trained by, DDC system manufacturer and responsible for execution of DDC system Work indicated.
- I. Distributed Control: Processing of system data is decentralized and control decisions are made at subsystem level. System operational programs and information are provided to remote subsystems and status is reported back. On loss of communication, subsystems shall be capable of operating in a standalone mode using the last best available data.
- J. DOCSIS: Data-Over Cable Service Interface Specifications.
- K. Gateway: Bidirectional protocol translator that connects control systems that use different communication protocols.
- L. HLC: Heavy load conditions.
- M. I/O: System through which information is received and transmitted. I/O refers to analog input (AI), binary input (BI), analog output (AO) and binary output (BO). Analog signals are continuous and represent control influences such as flow, level, moisture, pressure, and temperature. Binary signals convert electronic signals to digital pulses (values) and generally represent two-position operating and alarm status. "Digital," (DI and (DO), is sometimes used interchangeably with "Binary," (BI) and (BO), respectively.

- N. LAN: Local area network.
- O. LNS: LonWorks Network Services.
- P. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.
- Q. Mobile Device: A data-enabled phone or tablet computer capable of connecting to a cellular data network and running a native control application or accessing a web interface.
- R. Modbus TCP/IP: An open protocol for exchange of process data.
- S. MS/TP: Master-slave/token-passing, IEE 8802-3. Datalink protocol LAN option that uses twisted-pair wire for low-speed communication.
- T. MTBF: Mean time between failures.
- U. Network Controller: Digital controller, which supports a family of programmable application controllers and application-specific controllers, that communicates on peer-to-peer network for transmission of global data.
- V. Network Repeater: Device that receives data packet from one network and rebroadcasts it to another network. No routing information is added to protocol.
- W. Peer to Peer: Networking architecture that treats all network stations as equal partners.
- X. POT: Portable operator's terminal.
- Y. PUE: Performance usage effectiveness.
- Z. RAM: Random access memory.
- AA. RF: Radio frequency.
- BB. Router: Device connecting two or more networks at network layer.
- CC. Server: Computer used to maintain system configuration, historical and programming database.
- DD. TCP/IP: Transport control protocol/Internet protocol.
- EE. UPS: Uninterruptible power supply.
- FF. USB: Universal Serial Bus.
- GG. User Datagram Protocol (UDP): This protocol assumes that the IP is used as the underlying protocol.
- HH. VAV: Variable air volume.
- II. WLED: White light emitting diode.

1.4 ACTION SUBMITTALS

A. Multiple Submissions:

1. If multiple submissions are required to execute work within schedule, first submit a coordinated schedule clearly defining intent of multiple submissions. Include a proposed date of each submission with a detailed description of submittal content to be included in each submission.
2. Clearly identify each submittal requirement indicated and in which submission the information will be provided.
3. Include an updated schedule in each subsequent submission with changes highlighted to easily track the changes made to previous submitted schedule.

B. Product Data: For each type of product include the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.
4. Installation, operation and maintenance instructions including factors effecting performance.
5. Bill of materials of indicating quantity, manufacturer, and extended model number for each unique product.
 - a. Workstations.
 - b. Servers.
 - c. Gateways.
 - d. Routers.
 - e. Protocol analyzers.
 - f. DDC controllers.
 - g. Enclosures.
 - h. Electrical power devices.
 - i. UPS units.
 - j. Accessories.
 - k. Instruments.
 - l. Control dampers and actuators.
 - m. Control valves and actuators.
6. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.
7. Each submitted piece of product literature shall clearly cross reference specification and drawings that submittal is to cover.

C. Software Submittal:

1. Cross-referenced listing of software to be loaded on each operator workstation, server, gateway, and DDC controller.
2. Description and technical data of all software provided, and cross-referenced to products in which software will be installed.
3. Operating system software, operator interface and programming software, color graphic software, DDC controller software, maintenance management software, and third-party software.
4. Include a flow diagram and an outline of each subroutine that indicates each program variable name and units of measure.
5. Listing and description of each engineering equation used with reference source.

6. Listing and description of each constant used in engineering equations and a reference source to prove origin of each constant.
7. Description of operator interface to alphanumeric and graphic programming.
8. Description of each network communication protocol.
9. Description of system database, including all data included in database, database capacity and limitations to expand database.
10. Description of each application program and device drivers to be generated, including specific information on data acquisition and control strategies showing their relationship to system timing, speed, processing burden and system throughput.
11. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

D. Shop Drawings:

1. General Requirements:
 - a. Include cover drawing with Project name, location, Owner, Architect, Contractor and issue date with each Shop Drawings submission.
 - b. Include a drawing index sheet listing each drawing number and title that matches information in each title block.
2. Include plans, elevations, sections, and mounting details where applicable.
3. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
4. Detail means of vibration isolation and show attachments to rotating equipment.
5. Plan Drawings indicating the following:
 - a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork, and piping.
 - b. Room names and numbers with coordinated placement to avoid interference with control products indicated.
 - c. Each desktop workstation, server, gateway, router, DDC controller, control panel instrument connecting to DDC controller, and damper and valve connecting to DDC controller, if included in Project.
 - d. Exact placement of products in rooms, ducts, and piping to reflect proposed installed condition.
 - e. Network communication cable and raceway routing.
 - f. Proposed routing of wiring, cabling, conduit, and tubing, coordinated with building services for review before installation.
6. Schematic drawings for each controlled HVAC system indicating the following:
 - a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
 - b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.
 - c. A graphic showing location of control I/O in proper relationship to HVAC system.
 - d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
 - e. Unique identification of each I/O that shall be consistently used between different drawings showing same point.
 - f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays, and interface to DDC controllers.
 - g. Narrative sequence of operation.

- h. Graphic sequence of operation, showing all inputs and output logical blocks.
 - 7. Control panel drawings indicating the following:
 - a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
 - b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates, and allocated spare space.
 - c. Front, rear, and side elevations and nameplate legend.
 - d. Unique drawing for each panel.
 - 8. DDC system network riser diagram indicating the following:
 - a. Each device connected to network with unique identification for each.
 - b. Interconnection of each different network in DDC system.
 - c. For each network, indicate communication protocol, speed and physical means of interconnecting network devices, such as copper cable type, or optical fiber cable type. Indicate raceway type and size for each.
 - d. Each network port for connection of an operator workstation or other type of operator interface with unique identification for each.
 - 9. DDC system electrical power riser diagram indicating the following:
 - a. Each point of connection to field power with requirements (volts/phase/hertz/amperes/connection type) listed for each.
 - b. Each control power supply including, as applicable, transformers, power-line conditioners, transient voltage suppression and high filter noise units, DC power supplies, and UPS units with unique identification for each.
 - c. Each product requiring power with requirements (volts/phase/hertz/amperes/connection type) listed for each.
 - d. Power wiring type and size, race type, and size for each.
 - 10. Monitoring and control signal diagrams indicating the following:
 - a. Control signal cable and wiring between controllers and I/O.
 - b. Point-to-point schematic wiring diagrams for each product.
 - c. Control signal tubing to sensors, switches, and transmitters.
 - d. Process signal tubing to sensors, switches, and transmitters.
 - 11. Color graphics indicating the following:
 - a. Itemized list of color graphic displays to be provided.
 - b. For each display screen to be provided, a true color copy showing layout of pictures, graphics, and data displayed.
 - c. Intended operator access between related hierarchical display screens.
- E. System Description:
 - 1. Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.
 - 2. Complete listing and description of each report, log and trend for format and timing, and events which initiate generation.

3. System and product operation under each potential failure condition including, but not limited to, the following:
 - a. Loss of power.
 - b. Loss of network communication signal.
 - c. Loss of controller signals to inputs and outpoints.
 - d. Operator workstation failure.
 - e. Server failure.
 - f. Gateway failure.
 - g. Network failure
 - h. Controller failure.
 - i. Instrument failure.
 - j. Control damper and valve actuator failure.
4. Complete bibliography of documentation and media to be delivered to Owner.
5. Description of testing plans and procedures.
6. Description of Owner training.

1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data:

1. Systems Provider Qualification Data:

- a. Resume of project manager assigned to Project.
- b. Resumes of application engineering staff assigned to Project.
- c. Resumes of installation and programming technicians assigned to Project.
- d. Resumes of service technicians assigned to Project.
- e. Brief description of past project including physical address, floor area, number of floors, building system cooling and heating capacity, and building's primary function.
- f. Description of past project DDC system, noting similarities to Project scope and complexity indicated.
- g. Names of staff assigned to past project that will also be assigned to execute work of this Project.
- h. Owner contact information for past project including name, phone number, and e-mail address.
- i. Contractor contact information for past project including name, phone number, and e-mail address.

2. Manufacturer's qualification data.

B. Product Certificates:

1. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with ASHRAE 135.
2. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with LonWorks.

C. Field quality-control reports.

D. Sample Warranty: For manufacturer's warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For DDC system to include in emergency, operation, and maintenance manuals.
1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
 - a. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.
 - b. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
 - c. As-built versions of submittal Product Data.
 - d. Names, addresses, e-mail addresses, and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
 - e. Operator's manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing set points and variables.
 - f. Programming manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
 - g. Engineering, installation, and maintenance manuals that explain how to:
 - 1) Design and install new points, panels, and other hardware.
 - 2) Perform preventive maintenance and calibration.
 - 3) Debug hardware problems.
 - 4) Repair or replace hardware.
 - h. Documentation of all programs created using custom programming language including set points, tuning parameters, and object database.
 - i. Backup copy of graphic files, programs, and database on electronic media such as DVDs.
 - j. List of recommended spare parts with part numbers and suppliers.
 - k. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
 - l. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
 - m. Licenses, guarantees, and warranty documents.
 - n. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
 - o. Owner training materials.

1.7 QUALITY ASSURANCE

- A. DDC System Manufacturer Qualifications:
1. Nationally recognized manufacturer of DDC systems and products.
 2. DDC systems with similar requirements to those indicated for a continuous period of 10 years within time of bid.
 3. DDC systems and products that have been successfully tested and in use on at least five past projects.
 4. Having complete published catalog literature, installation, operation, and maintenance manuals for all products intended for use.

5. Having full-time in-house employees for the following:
 - a. Product research and development.
 - b. Product and application engineering.
 - c. Product manufacturing, testing, and quality control.
 - d. Technical support for DDC system installation training, commissioning, and troubleshooting of installations.
 - e. Owner operator training.

B. DDC System Provider Qualifications:

1. Authorized representative of, and trained by, DDC system manufacturer.
2. In-place facility located within 50 Miles of Project.
3. Demonstrated past experience with installation of DDC system products being installed for period within five consecutive years before time of bid.
4. Demonstrated past experience on five projects of similar complexity, scope, and value.
5. Each person assigned to Project shall have demonstrated past experience.
6. Staffing resources of competent and experienced full-time employees that are assigned to execute work according to schedule.
7. Service and maintenance staff assigned to support Project during warranty period.
8. Product parts inventory to support on-going DDC system operation for a period of not less than 5 years after Substantial Completion.
9. DDC system manufacturer's backing to take over execution of Work if necessary to comply with requirements indicated. Include Project-specific written letter, signed by manufacturer's corporate officer, if requested.

C. Testing Agency Qualifications: Member company of NETA.

1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

D. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."
3. AWS D1.3/D1.3M, "Structural Welding Code - Sheet Steel."
4. AWS D1.4/D1.4M, "Structural Welding Code - Reinforcing Steel."

E. Pipe and Pressure-Vessel Welding Qualifications: Qualify procedures and operators according to "ASME Boiler and Pressure Vessel Code."

F. Mockups: Build mockups to verify selections made under Sample submittals, to demonstrate aesthetic effects, and to set quality standards for materials and products and for fabrication and installation.

1. Build mockups of completed installation for areas indicated on Drawings.
2. Approval of mockups does not constitute approval of deviations from Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.

1.8 WARRANTY

A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period.

1. Failures shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.

2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.
 - a. Install updates only after receiving Owner's written authorization.
3. Warranty service shall occur during normal business hours and commence within 24 hours of Owner's warranty service request.
4. Warranty Period: Two year(s) from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 DDC SYSTEM MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Johnson Controls, Inc.

2.2 DDC SYSTEM DESCRIPTION

- A. Microprocessor-based monitoring and control including analog/digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices to achieve a set of predefined conditions.
1. DDC system shall consist of a high-speed, peer-to-peer network of distributed DDC controllers, other network devices, operator interfaces, and software.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 WEB ACCESS

- A. DDC system shall be web based.

1. Web-Based Access to DDC System:
 - a. DDC system software shall be based on server thin-client architecture, designed around open standards of web technology. DDC system server shall be accessed using a web browser over DDC system network, using Owner's LAN, and remotely over Internet through Owner's LAN.
 - b. Intent of thin-client architecture is to provide operators complete access to DDC system via a web browser. No special software other than a web browser shall be required to access graphics, point displays, and trends; to configure trends, points, and controllers; and to edit programming.
 - c. Web access shall be password protected.

2.4 PERFORMANCE REQUIREMENTS

- A. Delegated Design, Qualified Professional Engineer: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design DDC system to satisfy requirements indicated.

- B. Delegated Design, Qualified Professional: Engage a qualified professional to design DDC system to satisfy requirements indicated.
1. System Performance Objectives:
- DDC system shall manage HVAC systems.
 - DDC system control shall operate HVAC systems to achieve optimum operating costs while using least possible energy and maintaining specified performance.
 - DDC system shall respond to power failures, HVAC equipment failures, and adverse and emergency conditions encountered through connected I/O points.
 - DDC system shall operate while unattended by an operator and through operator interaction.
 - DDC system shall record trends and transaction of events and produce report information such as performance, energy, occupancies, and equipment operation.
- C. Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths shall comply with ASTM E84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
- Flame-Spread Index: 25 or less.
 - Smoke-Developed Index: 50 or less.
- D. DDC System Speed:
1. Response Time of Connected I/O:
- AI point values connected to DDC system shall be updated at least every five seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
 - BI point values connected to DDC system shall be updated at least every five seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
 - AO points connected to DDC system shall begin to respond to controller output commands within two second(s). Global commands shall also comply with this requirement.
 - BO point values connected to DDC system shall respond to controller output commands within two second(s). Global commands shall also comply with this requirement.
2. Display of Connected I/O:
- Analog point COV connected to DDC system shall be updated and displayed at least every 10 seconds for use by operator.
 - Binary point COV connected to DDC system shall be updated and displayed at least every 10 seconds for use by operator.
 - Alarms of analog and digital points connected to DDC system shall be displayed within 30 seconds of activation or change of state.
 - Graphic display refresh shall update within eight seconds.
 - Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations shall not exceed graphic refresh rate indicated.
- E. Network Bandwidth: Design each network of DDC system to include at least 30 percent available spare bandwidth with DDC system operating under normal and heavy load conditions indicated. Calculate bandwidth usage, and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions.

F. DDC System Data Storage:

1. Include capability to archive not less than 60 consecutive months of historical data for all I/O points connected to system, including alarms, event histories, transaction logs, trends and other information indicated.

G. DDC Data Access:

1. When logged into the system, operator shall be able to also interact with any DDC controller connected to DDC system as required for functional operation of DDC system.
2. System(s) shall be used for application configuration; for archiving, reporting and trending of data; for operator transaction archiving and reporting; for network information management; for alarm annunciation; and for operator interface tasks and controls application management.

H. Future Expandability:

1. DDC system size shall be expandable to an ultimate capacity of at least two times total I/O points indicated.
2. Additional DDC controllers, I/O and associated wiring shall be all that is needed to achieve ultimate capacity. Initial network infrastructure shall be designed and installed to support ultimate capacity.
3. Operator interfaces installed initially shall not require hardware and software additions and revisions for ultimate capacity.

I. Input Point Displayed Accuracy: Input point displayed values shall meet following end-to-end overall system accuracy, including errors associated with meter, sensor, transmitter, lead wire or cable, and analog to digital conversion.

1. Energy:
 - a. Thermal: Within 1 percent of reading.
 - b. Electric Power: Within 1 percent of reading.
 - c. Requirements indicated on Drawings for meters not supplied by utility.
2. Flow:
 - a. Air: Within 5 percent of design flow rate.
 - b. Air (Terminal Units): Within 10 percent of design flow rate.
 - c. Water: Within 2 percent of design flow rate.
 - d. Steam: Within 5 percent of design flow rate.
3. Gas:
 - a. Carbon Dioxide: Within 50 ppm.
 - b. Carbon Monoxide: Within 5 percent of reading.
 - c. Oxygen: Within 5 percent of reading.
 - d. Refrigerant: Within 50 ppm.
4. Moisture (Relative Humidity):
 - a. Air: Within 2 percent RH.
 - b. Space: Within 2 percent RH.
 - c. Outdoor: Within 2 percent RH.
5. Level: Within 2 percent of reading.

6. Pressure:
 - a. Air, Ducts and Equipment: 0.5 percent of instrument span.
 - b. Space: Within 0.25 percent of instrument span.
 - c. Water: Within 0.5 percent of instrument span.
 - d. Steam: Within 0.5 percent of instrument span.
 7. Speed: Within 5 percent of reading.
 8. Temperature, Dew Point:
 - a. Air: Within 0.5 deg F.
 - b. Space: Within 0.5 deg F.
 - c. Outdoor: Within 2 deg F.
 9. Temperature, Dry Bulb:
 - a. Air: Within 0.5 deg F.
 - b. Space: Within 0.5 deg F.
 - c. Outdoor: Within 1 deg F.
 - d. Chilled Water: Within 0.5 deg F.
 - e. Condenser Water: Within 0.5 deg F.
 - f. Heating Hot Water: Within 0.5 deg F.
 - g. Energy Recovery Runaround Liquid: Within 0.5 deg F.
 - h. Steam: Within 1 deg F.
 - i. Temperature Difference: Within 0.25 deg F.
 - j. Other Temperatures Not Indicated: Within 0.5 deg F.
 10. Temperature, Wet Bulb:
 - a. Air: Within 0.5 deg F.
 - b. Space: Within 0.5 deg F.
 - c. Outdoor: Within 1 deg F.
 11. Vibration: Within 5 percent of reading.
- J. Precision of I/O Reported Values: Values reported in database and displayed shall have following precision:
1. Current:
 - a. Milliamperes: Nearest 1/100th of a milliampere.
 - b. Amperes: Nearest 1/10th of an ampere up to 100 A; nearest ampere for 100 A and more.
 2. Energy:
 - a. Electric Power:
 - 1) Rate (Watts): Nearest 1/10th of a watt through 1000 W.
 - 2) Rate (Kilowatts): Nearest 1/10th of a kilowatt through 1000 kW; nearest kilowatt above 1000 kW.
 - 3) Usage (Kilowatt-Hours): Nearest kilowatt through 10,000 kW; nearest 10 kW between 10,000 and 100,000 kW; nearest 100 kW for above 100,000 kW.

- b. Thermal, Rate:
 - 1) Heating: For Btu/h, nearest Btu/h up to 1000 Btu/h; nearest 10 Btu/h between 1000 and 10,000 Btu/h; nearest 100 Btu/h for above 10,000 Btu/h. For Mbh, round to nearest Mbh up to 1000 Mbh; nearest 10 Mbh between 1000 and 10,000 Mbh; nearest 100 Mbh above 10,000 Mbh.
 - 2) Cooling: For tons, nearest ton up to 1000 tons; nearest 10 tons between 1000 and 10,000 tons; nearest 100 tons above 10,000 tons.
- c. Thermal, Usage:
 - 1) Heating: For Btu, nearest Btu up to 1000 Btu; nearest 10 Btu between 1000 and 10,000 Btu; nearest 100 Btu for above 10,000 Btu. For Mbtu, round to nearest Mbtu up to 1000 Mbtu; nearest 10 Mbtu between 1000 and 10,000 Mbtu; nearest 100 Mbtu above 10,000 Mbtu.
 - 2) Cooling: For ton-hours, nearest ton-hours up to 1000 ton-hours; nearest 10 ton-hours between 1000 and 10,000 ton-hours; nearest 100 tons above 10,000 tons.
- 3. Flow:
 - a. Water: Nearest 1/10th gpm through 100 gpm; nearest gpm between 100 and 1000 gpm; nearest 10 gpm between 1000 and 10,000 gpm; nearest 100 gpm above 10,000 gpm.
- 4. Gas:
 - a. Carbon Dioxide (ppm): Nearest ppm.
 - b. Carbon Monoxide (ppm): Nearest ppm.
 - c. Oxygen (Percentage): Nearest 1/10th of 1 percent.
 - d. Refrigerant (ppm): Nearest ppm.
- 5. Moisture (Relative Humidity):
 - a. Relative Humidity (Percentage): Nearest 1 percent.
- 6. Level: Nearest 1/100th of an inch through 10 inches; nearest 1/10 of an inch between 10 and 100 inches; nearest inch above 100 inches.
- 7. Speed:
 - a. Rotation (rpm): Nearest 1 rpm.
 - b. Velocity: Nearest 1/10th fpm through 100 fpm; nearest fpm between 100 and 1000 fpm; nearest 10 fpm above 1000 fpm.
- 8. Position, Dampers and Valves (Percentage Open): Nearest 1 percent.
- 9. Pressure:
 - a. Air, Ducts and Equipment: Nearest 1/10th in. w.c.
 - b. Space: Nearest 1/100th in. w.c.
 - c. Steam: Nearest 1/10th psig through 100 psig; nearest psig above 100 psig.
 - d. Water: Nearest 1/10 psig through 100 psig; nearest psig above 100 psig.
- 10. Temperature:
 - a. Air, Ducts and Equipment: Nearest 1/10th of a degree.
 - b. Outdoor: Nearest degree.
 - c. Space: Nearest 1/10th of a degree.
 - d. Chilled Water: Nearest 1/10th of a degree.

- e. Condenser Water: Nearest 1/10th of a degree.
 - f. Heating Hot Water: Nearest degree.
 - g. Heat Recovery Runaround: Nearest 1/10th of a degree.
 - h. Steam: Nearest degree.
- 11. Vibration: Nearest 1/10th in/s.
- 12. Voltage: Nearest 1/10 volt up to 100 V; nearest volt above 100 V.
- K. Control Stability: Control variables indicated within the following limits:
 - 1. Flow:
 - a. Air, Ducts and Equipment, except Terminal Units: Within 2 percent of design flow rate.
 - b. Air, Terminal Units: Within 10 percent of design flow rate.
 - c. Water: Within 2 percent of design flow rate.
 - 2. Gas:
 - a. Carbon Dioxide: Within 50 ppm.
 - b. Carbon Monoxide: Within 5 percent of reading.
 - c. Oxygen: Within 5 percent of reading.
 - 3. Moisture (Relative Humidity):
 - a. Air: Within 2 percent RH.
 - b. Space: Within 2 percent RH.
 - c. Outdoor: Within 2 percent RH.
 - 4. Level: Within 5 percent of reading.
 - 5. Pressure:
 - a. Air, Ducts and Equipment: 0.5 percent of instrument span.
 - b. Space: Within 0.25 percent of instrument span.
 - c. Water: Within 0.5 percent of instrument span.
 - 6. Temperature, Dew Point:
 - a. Air: Within 0.5 deg F.
 - b. Space: Within 0.5 deg F.
 - 7. Temperature, Dry Bulb:
 - a. Air: Within 0.5 deg F.
 - b. Space: Within 0.5 deg F.
 - c. Chilled Water: Within 0.5 deg F.
 - d. Condenser Water: Within 0.5 deg F.
 - e. Heating Hot Water: Within 0.5 deg F.
 - f. Energy Recovery Runaround Liquid: Within 0.5 deg F.
 - 8. Temperature, Wet Bulb:
 - a. Air: Within 0.5 deg F.
 - b. Space: Within 0.5 deg F.

L. Environmental Conditions for Controllers, Gateways, and Routers:

1. Products shall operate without performance degradation under ambient environmental temperature, pressure and humidity conditions encountered for installed location.
 - a. If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, cooled and ventilated as required by product and application.
2. Products shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Products not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: Type 2.
 - b. Indoors, Heated and Air Conditioned: Type 1.
 - c. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: Type 12.
 - 2) Air-Moving Equipment Rooms: Type 1.

M. Environmental Conditions for Instruments and Actuators:

1. Instruments and actuators shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
 - a. If instruments and actuators alone cannot comply with requirement, install instruments and actuators in protective enclosures that are isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated and ventilated as required by instrument and application.
2. Instruments, actuators and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments and actuators not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:
 - a. Outdoors, Unprotected: Type 4X.
 - b. Indoors, Heated with Non-Filtered Ventilation: Type 2.
 - c. Indoors, Heated and Air-conditioned: Type 1.
 - d. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: Type 12.
 - 2) Air-Moving Equipment Rooms: Type 1.
 - e. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 2.

N. DDC System Reliability:

1. Design, install and configure DDC controllers, gateways, routers, to yield a MTBF of at least 40,000 hours, based on a confidence level of at least 90 percent. MTBF value shall include any failure for any reason to any part of products indicated.

2. If required to comply with MTBF indicated, include DDC system and product redundancy to maintain DCC system, and associated systems and equipment that are being controlled, operational and under automatic control.
3. Critical systems and equipment that require a higher degree of DDC system redundancy than MTBF indicated shall be indicated on Drawings.

O. Electric Power Quality:

1. Power-Line Surges:
 - a. Protect susceptible DDC system products connected to ac power circuits from power-line surges to comply with requirements of IEEE C62.41.
 - b. Do not use fuses for surge protection.
 - c. Test protection in the normal mode and in the common mode, using the following two waveforms:
 - 1) 10-by-1000-mic.sec. waveform with a peak voltage of 1500 V and a peak current of 60 A.
 - 2) 8-by-20-mic.sec. waveform with a peak voltage of 1000 V and a peak current of 500 A.
2. Power Conditioning:
 - a. Protect susceptible DDC system products connected to ac power circuits from irregularities and noise rejection. Characteristics of power-line conditioner shall be as follows:
 - 1) At 85 percent load, output voltage shall not deviate by more than plus or minus 1 percent of nominal when input voltage fluctuates between minus 20 percent to plus 10 percent of nominal.
 - 2) During load changes from zero to full load, output voltage shall not deviate by more than plus or minus 3 percent of nominal.
 - 3) Accomplish full correction of load switching disturbances within five cycles, and 95 percent correction within two cycles of onset of disturbance.
 - 4) Total harmonic distortion shall not exceed 3-1/2 percent at full load.
3. Ground Fault: Protect products from ground fault by providing suitable grounding. Products shall not fail due to ground fault condition.

P. Backup Power Source:

1. HVAC systems and equipment served by a backup power source shall have associated DDC system products that control such systems and equipment also served from a backup power source.

Q. UPS:

1. DDC system products powered by UPS units shall include the following:
 - a. DDC controllers, except application-specific controllers.

R. Continuity of Operation after Electric Power Interruption:

1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems shall automatically return equipment and associated controls to operating state occurring immediately before loss of normal power, without need for manual intervention by operator when power is restored either

through backup power source or through normal power if restored before backup power is brought online.

2.5 SYSTEM ARCHITECTURE

- A. System architecture shall consist of no more than three levels of LANs.
 - 1. Level one LAN shall connect network controllers and operator workstations.
 - 2. Level one or Level two LAN shall connect programmable application controllers to other programmable application controllers, and to network controllers.
 - 3. Level two or Level three LAN shall connect application-specific controllers to programmable application controllers and network controllers.
 - 4. Level two or Level three LAN shall connect application-specific controllers to application-specific controllers.
- B. Minimum Data Transfer and Communication Speed:
 - 1. LAN Connecting Operator Workstations and Network Controllers: 100 Mbps.
 - 2. LAN Connecting Programmable Application Controllers: 100 kbps.
 - 3. LAN Connecting Application-Specific Controllers: 38,400 bps.
- C. DDC system shall consist of dedicated and separated LANs that are not shared with other building systems and tenant data and communication networks.
- D. System architecture shall be modular and have inherent ability to expand to not less than three times system size indicated with no impact to performance indicated.
- E. System architecture shall perform modifications without having to remove and replace existing network equipment.
- F. Number of LANs and associated communication shall be transparent to operator. All I/O points residing on any LAN shall be capable of global sharing between all system LANs.
- G. System design shall eliminate dependence on any single device for system alarm reporting and control execution. Each controller shall operate independently by performing its' own control, alarm management and historical data collection.
- H. Special Network Architecture Requirements:
 - 1. Air-Handling Systems: For control applications of an air-handling system that consists of air-handling unit(s) and VAV terminal units, include a dedicated LAN of application-specific controllers serving VAV terminal units connected directly to controller that is controlling air-handling system air-handling unit(s). Basically, create a DDC system LAN that aligns with air-handling system being controlled.

2.6 DDC SYSTEM OPERATOR INTERFACES

- A. Operator Means of System Access: Operator shall be able to access entire DDC system through any of multiple means, including, but not limited to, the following:
 - 1. Remote connection through web access.
- B. Access to system, regardless of operator means used, shall be transparent to operator.

- C. Network Ports: For hardwired connection of desktop or portable workstation. Network port shall be easily accessible, properly protected, clearly labeled, and installed at the following locations:
 - 1. Each boiler room.
 - 2. Each chiller room or outdoor chiller yard.
 - 3. Each different roof level with roof-mounted air-handling units or rooftop units.
- D. Mobile Device:
 - 1. Connect to system through a wireless router connected to LAN and cellular data service.
 - 2. Able to communicate with any DDC controller connected to DDC system using a dedicated application and secure web access.
- E. Critical Alarm Reporting:
 - 1. Operator-selected critical alarms shall be sent by DDC system to notify operator of critical alarms that require immediate attention.
 - 2. DDC system shall send alarm notification to multiple recipients that are assigned for each alarm.
 - 3. DDC system shall notify recipients by any or all means, including e-mail, text message and prerecorded phone message to mobile and landline phone numbers.
- F. Simultaneous Operator Use: Capable of accommodating up to 20 simultaneous operators that are accessing DDC system through any one of operator interfaces indicated.

2.7 NETWORKS

- A. Acceptable networks for connecting workstations, mobile devices, and network controllers include the following:
 - 1. IP.
 - 2. IEEE 8802-3, Ethernet.
- B. Acceptable networks for connecting programmable application controllers include the following:
 - 1. IP.
 - 2. IEEE 8802-3, Ethernet.
- C. Acceptable networks for connecting application-specific controllers include the following:
 - 1. IP.

2.8 NETWORK COMMUNICATION PROTOCOL

- A. Network communication protocol(s) used throughout entire DDC system shall be open to Owner and available to other companies for use in making future modifications to DDC system.
- B. ASHRAE 135 Protocol:
 - 1. ASHRAE 135 communication protocol shall be sole and native protocol used throughout entire DDC system.
 - 2. DDC system shall not require use of gateways except to integrate HVAC equipment and other building systems and equipment, not required to use ASHRAE 135 communication protocol.

3. If used, gateways shall connect to DDC system using ASHRAE 135 communication protocol and Project object properties and read/write services indicated by interoperability schedule.
4. Operator workstations, controllers and other network devices shall be tested and listed by BACnet Testing Laboratories.

C. Industry Standard Protocols:

1. DDC system shall use any one or a combination of the following industry standard protocols for network communication while complying with other DDC system requirements indicated:
 - a. ASHRAE 135.
 - b. Modbus Application Protocol Specification V1.1b.
2. Operator workstations and network controllers shall communicate through ASHRAE 135 or CEA-709.1-C protocol.
3. Portions of DDC system networks using ASHRAE 135 communication protocol shall be an open implementation of network devices complying with ASHRAE 135. Network devices shall be tested and listed by BACnet Testing Laboratories.
4. Portions of DDC system networks using Modbus Application Protocol Specification V1.1b communication protocol shall be an open implementation of network devices and technology complying with Modbus Application Protocol Specification V1.1b.
5. Gateways shall be used to connect networks and network devices using different protocols.

2.9 SERVERS

- A. Control System shall connect to existing ADX Server serving the Government Center. Server shall be upgraded to most current released version of Metasys. Include SLA for patches and upgrades through warranty period.

2.10 SYSTEM SOFTWARE

A. System Software Minimum Requirements:

1. Real-time multitasking and multiuser 64-bit operating system that allows concurrent multiple operator workstations operating and concurrent execution of multiple real-time programs and custom program development.
2. Operating system shall be capable of operating Microsoft Windows applications.
3. Database management software shall manage all data on an integrated and non-redundant basis. Additions and deletions to database shall be without detriment to existing data. Include cross linkages so no data required by a program can be deleted by an operator until that data have been deleted from respective programs.
4. Network communications software shall manage and control multiple network communications to provide exchange of global information and execution of global programs.
5. Operator interface software shall include day-to-day operator transaction processing, alarm and report handling, operator privilege level and data segregation control, custom programming, and online data modification capability.
6. Scheduling software shall schedule centrally based time and event, temporary, and exception day programs.

B. Operator Interface Software:

1. Minimize operator training through use of English language prorating and English language point identification.

2. Minimize use of a typewriter-style keyboard through use of a pointing device similar to a mouse.
3. Operator sign-off shall be a manual operation or, if no keyboard or mouse activity takes place, an automatic sign-off.
4. Automatic sign-off period shall be programmable from one to 60 minutes in one-minute increments on a per operator basis.
5. Operator sign-on and sign-off activity shall be recorded and sent to printer.
6. Security Access:
 - a. Operator access to DDC system shall be under password control.
 - b. An alphanumeric password shall be field assignable to each operator.
 - c. Operators shall be able to access DDC system by entry of proper password.
 - d. Operator password shall be same regardless of which computer or other interface means is used.
 - e. Additions or changes made to passwords shall be updated automatically.
 - f. Each operator shall be assigned an access level to restrict access to data and functions the operator is capable of performing.
 - g. Software shall have at least five access levels.
 - h. Each menu item shall be assigned an access level so that a one-for-one correspondence between operator assigned access level(s) and menu item access level(s) is required to gain access to menu item.
 - i. Display menu items to operator with those capable of access highlighted. Menu and operator access level assignments shall be online programmable and under password control.
7. Data Segregation:
 - a. Include data segregation for control of specific data routed to a workstation, to an operator or to a specific output device, such as a printer.
 - b. Include at least 32 segregation groups.
 - c. Segregation groups shall be selectable such as "fire points," "fire points on second floor," "space temperature points," "HVAC points," and so on.
 - d. Points shall be assignable to multiple segregation groups. Display and output of data to printer or monitor shall occur where there is a match of operator or peripheral segregation group assignment and point segregations.
 - e. Alarms shall be displayed and printed at each peripheral to which segregation allows, but only those operators assigned to peripheral and having proper authorization level will be allowed to acknowledge alarms.
 - f. Operators and peripherals shall be assignable to multiple segregation groups and all assignments are to be online programmable and under password control.
8. Operators shall be able to perform commands including, but not limited to, the following:
 - a. Start or stop selected equipment.
 - b. Adjust set points.
 - c. Add, modify, and delete time programming.
 - d. Enable and disable process execution.
 - e. Lock and unlock alarm reporting for each point.
 - f. Enable and disable totalization for each point.
 - g. Enable and disable trending for each point.
 - h. Override control loop set points.
 - i. Enter temporary override schedules.
 - j. Define holiday schedules.
 - k. Change time and date.
 - l. Enter and modify analog alarm limits.
 - m. Enter and modify analog warning limits.
 - n. View limits.
 - o. Enable and disable demand limiting.

- p. Enable and disable duty cycle.
- q. Display logic programming for each control sequence.
- 9. Reporting:
 - a. Generated automatically and manually.
 - b. Sent to displays, printers and disk files.
 - c. Types of Reporting:
 - 1) General listing of points.
 - 2) List points currently in alarm.
 - 3) List of off-line points.
 - 4) List points currently in override status.
 - 5) List of disabled points.
 - 6) List points currently locked out.
 - 7) List of items defined in a "Follow-Up" file.
 - 8) List weekly schedules.
 - 9) List holiday programming.
 - 10) List of limits and deadbands.
- 10. Summaries: For specific points, for a logical point group, for an operator selected group(s), or for entire system without restriction due to hardware configuration.

C. Graphic Interface Software:

- 1. Include a full interactive graphical selection means of accessing and displaying system data to operator. Include at least five levels with the penetration path operator assignable (for example, site, building, floor, air-handling unit, and supply temperature loop). Native language descriptors assigned to menu items are to be operator defined and modifiable under password control.
- 2. Include a hierarchical-linked dynamic graphic operator interface for accessing and displaying system data and commanding and modifying equipment operation. Interface shall use a pointing device with pull-down or penetrating menus, color and animation to facilitate operator understanding of system.
- 3. Include at least 10 levels of graphic penetration with the hierarchy operator assignable.
- 4. Descriptors for graphics, points, alarms and such shall be modified through operator's workstation under password control.
- 5. Graphic displays shall be online user definable and modifiable using the hardware and software provided.
- 6. Data to be displayed within a graphic shall be assignable regardless of physical hardware address, communication or point type.
- 7. Graphics are to be online programmable and under password control.
- 8. Points may be assignable to multiple graphics where necessary to facilitate operator understanding of system operation.
- 9. Graphics shall also contain software points.
- 10. Penetration within a graphic hierarchy shall display each graphic name as graphics are selected to facilitate operator understanding.
- 11. Back-trace feature shall permit operator to move upward in the hierarchy using a pointing device. Back trace shall show all previous penetration levels. Include operator with option of showing each graphic full screen size with back trace as horizontal header or by showing a "stack" of graphics, each with a back trace.
- 12. Display operator accessed data on the monitor.
- 13. Operator shall select further penetration using pointing device to click on a site, building, floor, area, equipment, and so on. Defined and linked graphic below that selection shall then be displayed.
- 14. Include operator with means to directly access graphics without going through penetration path.
- 15. Dynamic data shall be assignable to graphics.

16. Display points (physical and software) with dynamic data provided by DDC system with appropriate text descriptors, status or value, and engineering unit.
 17. Use color, rotation, or other highly visible means, to denote status and alarm states. Color shall be variable for each class of points, as chosen by operator.
 18. Points shall be dynamic with operator adjustable update rates on a per point basis from one second to over a minute.
 19. For operators with appropriate privilege, points shall be commanded directly from display using pointing device.
 - a. For an analog command point such as set point, current conditions and limits shall be displayed and operator can position new set point using pointing device.
 - b. For a digital command point such as valve position, valve shall show its current state such as open or closed and operator could select alternative position using pointing device.
 - c. Keyboard equivalent shall be available for those operators with that preference.
 20. Operator shall be able to split or resize viewing screen into quadrants to show one graphic on one quadrant of screen and other graphics or spreadsheet, bar chart, word processing, curve plot and other information on other quadrants on screen. This feature shall allow real-time monitoring of one part of system while displaying other parts of system or data to better facilitate overall system operation.
 21. Help Features:
 - a. On-line context-sensitive help utility to facilitate operator training and understanding.
 - b. Bridge to further explanation of selected keywords. Document shall contain text and graphics to clarify system operation.
 - 1) If help feature does not have ability to bridge on keywords for more information, a complete set of user manuals shall be provided in an indexed word-processing program, which shall run concurrently with operating system software.
 - c. Available for Every Menu Item:
 - 1) Index items for each system menu item.
 22. Graphic generation software shall allow operator to add, modify, or delete system graphic displays.
 - a. Include libraries of symbols depicting HVAC symbols such as fans, coils, filters, dampers, valves pumps, and electrical symbols similar to those indicated.
 - b. Graphic development package shall use a pointing device in conjunction with a drawing program to allow operator to perform the following:
 - 1) Define background screens.
 - 2) Define connecting lines and curves.
 - 3) Locate, orient and size descriptive text.
 - 4) Define and display colors for all elements.
 - 5) Establish correlation between symbols or text and associated system points or other displays.
- D. Project-Specific Graphics: Graphics documentation including, but not limited to, the following:
1. Site plan showing each building, and additional site elements, which are being controlled or monitored by DDC system.

2. Plan for each building floor, including interstitial floors, and each roof level of each building, showing the following:
 - a. Room layouts with room identification and name.
 - b. Locations and identification of all monitored and controlled HVAC equipment and other equipment being monitored and controlled by DDC system.
 - c. Location and identification of each hardware point being controlled or monitored by DDC system.
 3. Control schematic for each of following, including a graphic system schematic representation, similar to that indicated on Drawings, with point identification, set point and dynamic value indication , sequence of operation and control logic diagram.
 4. Graphic display for each piece of equipment connected to DDC system through a data communications link. Include dynamic indication of all points associated with equipment.
 5. DDC system network riser diagram that shows schematic layout for entire system including all networks and all controllers, gateways operator workstations and other network devices.
- E. Customizing Software:
1. Software to modify and tailor DDC system to specific and unique requirements of equipment installed, to programs implemented and to staffing and operational practices planned.
 2. Online modification of DDC system configuration, program parameters, and database using menu selection and keyboard entry of data into preformatted display templates.
 3. As a minimum, include the following modification capability:
 - a. Operator assignment shall include designation of operator passwords, access levels, point segregation and auto sign-off.
 - b. Peripheral assignment capability shall include assignment of segregation groups and operators to consoles and printers, designation of backup workstations and printers, designation of workstation header points and enabling and disabling of print-out of operator changes.
 - c. System configuration and diagnostic capability shall include communications and peripheral port assignments, DDC controller assignments to network, DDC controller enable and disable, assignment of command trace to points and application programs and initiation of diagnostics.
 - d. System text addition and change capability shall include English or native language descriptors for points, segregation groups and access levels and action messages for alarms, run time and trouble condition.
 - e. Time and schedule change capability shall include time and date set, time and occupancy schedules, exception and holiday schedules and daylight savings time schedules.
 - f. Point related change capability shall include the following:
 - 1) System and point enable and disable.
 - 2) Run-time enable and disable.
 - 3) Assignment of points to segregation groups, calibration tables, lockout, and run time and to a fixed I/O value.
 - 4) Assignment of alarm and warning limits.
 - g. Application program change capability shall include the following:
 - 1) Enable and disable of software programs.
 - 2) Programming changes.
 - 3) Assignment of comfort limits, global points, time and event initiators, time and event schedules and enable and disable time and event programs.

4. Software shall allow operator to add points, or groups of points, to DDC system and to link them to energy optimization and management programs. Additions and modifications shall be online programmable using operator workstation, downloaded to other network devices and entered into their databases. After verification of point additions and associated program operation, database shall be uploaded and recorded on hard drive and disk for archived record.
5. Include high-level language programming software capability for implementation of custom DDC programs. Software shall include a compiler, linker, and up- and down-load capability.
6. Include a library of DDC algorithms, intrinsic control operators, arithmetic, logic and relational operators for implementation of control sequences. Also include, as a minimum, the following:
 - a. Proportional control (P).
 - b. Proportional plus integral (PI).
 - c. Proportional plus integral plus derivative (PID).
 - d. Adaptive and intelligent self-learning control.
 - 1) Algorithm shall monitor loop response to output corrections and adjust loop response characteristics according to time constant changes imposed.
 - 2) Algorithm shall operate in a continuous self-learning manner and shall retain in memory a stored record of system dynamics so that on system shut down and restart, learning process starts from where it left off.
7. Fully implemented intrinsic control operators including sequence, reversing, ratio, time delay, time of day, highest select AO, lowest select AO, analog controlled digital output, analog control AO, and digitally controlled AO.
8. Logic operators such as "And," "Or," "Not," and others that are part of a standard set available with a high-level language.
9. Arithmetic operators such as "Add," "Subtract," "Multiply," "Divide," and others that are part of a standard set available with a high-level language.
10. Relational operators such as "Equal To," "Not Equal To," "Less Than," "Greater Than," and others that are part of a standard set available with a high-level language.

F. Alarm Handling Software:

1. Include alarm handling software to report all alarm conditions monitored and transmitted through DDC controllers , gateways and other network devices.
2. Include first in, first out handling of alarms according to alarm priority ranking, with most critical alarms first, and with buffer storage in case of simultaneous and multiple alarms.
3. Alarm handling shall be active at all times to ensure that alarms are processed even if an operator is not currently signed on to DDC system.
4. Alarms display shall include the following:
 - a. Indication of alarm condition such as "Abnormal Off," "Hi Alarm," and "Low Alarm."
 - b. "Analog Value" or "Status" group and point identification with native language point descriptor such as "Space Temperature, Building 110, 2nd Floor, Room 212."
 - c. Discrete per point alarm action message, such as "Call Maintenance Dept. Ext-5561."
 - d. Include extended message capability to allow assignment and printing of extended action messages. Capability shall be operator programmable and assignable on a per point basis.
5. Alarms shall be directed to appropriate operator workstations, printers, and individual operators by privilege level and segregation assignments.
6. Send e-mail alarm messages to designated operators.
7. Send e-mail, page, text and voice messages to designated operators for critical alarms.

8. Alarms shall be categorized and processed by class.
 - a. Class 1:
 - 1) Associated with fire, security and other extremely critical equipment monitoring functions; have alarm, trouble, return to normal, and acknowledge conditions printed and displayed.
 - 2) Unacknowledged alarms to be placed in unacknowledged alarm buffer.
 - 3) All conditions shall cause an audible sound and shall require individual acknowledgment to silence audible sound.
 - b. Class 2:
 - 1) Critical, but not life-safety related, and processed same as Class 1 alarms, except do not require individual acknowledgment.
 - 2) Acknowledgement may be through a multiple alarm acknowledgment.
 - c. Class 3:
 - 1) General alarms; printed, displayed and placed in unacknowledged alarm buffer queues.
 - 2) Each new alarm received shall cause an audible sound. Audible sound shall be silenced by "acknowledging" alarm or by pressing a "silence" key.
 - 3) Acknowledgement of queued alarms shall be either on an individual basis or through a multiple alarm acknowledgement.
 - 4) Alarms returning to normal condition shall be printed and not cause an audible sound or require acknowledgment.
 - d. Class 4:
 - 1) Routine maintenance or other types of warning alarms.
 - 2) Alarms to be printed only, with no display, no audible sound and no acknowledgment required.
9. Include an unacknowledged alarm indicator on display to alert operator that there are unacknowledged alarms in system. Operator shall be able to acknowledge alarms on an individual basis or through a multiple alarm acknowledge key, depending on alarm class.
10. To ensure that no alarm records are lost, it shall be possible to assign a backup printer to accept alarms in case of failure of primary printer.

G. Reports and Logs:

1. Include reporting software package that allows operator to select, modify, or create reports using DDC system I/O point data available.
2. Each report shall be definable as to data content, format, interval and date.
3. Report data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on server for historical reporting.
4. Operator shall be able to obtain real-time logs of all I/O points by type or status, such as alarm, point lockout, or normal.
5. Reports and logs shall be stored on server hard drives in a format that is readily accessible by other standard software applications, including spreadsheets and word processing.
6. Reports and logs shall be readily printed and set to be printed either on operator command or at a specific time each day.

- H. Standard Reports: Standard DDC system reports shall be provided and operator shall be able to customize reports later.
1. All I/O: With current status and values.
 2. Alarm: All current alarms, except those in alarm lockout.
 3. Disabled I/O: All I/O points that are disabled.
 4. Alarm Lockout I/O: All I/O points in alarm lockout, whether manual or automatic.
 5. Alarm Lockout I/O in Alarm: All I/O in alarm lockout that are currently in alarm.
 6. Logs:
 - a. Alarm history.
 - b. System messages.
 - c. System events.
 - d. Trends.
- I. Tenant Override Reports: Prepare Project-specific reports.
1. Weekly report showing daily total time in hours that each tenant has requested after-hours HVAC.
 2. Monthly report showing daily total time in hours that each tenant has requested after-hours HVAC.
 3. Annual summary report that shows after-hours HVAC usage on a monthly basis.
- J. HVAC Equipment Reports: Prepare Project-specific reports.
1. Chiller Report: Daily report showing operating conditions of each chiller according to ASHRAE 147, including, but not limited to, the following:
 - a. Chilled-water entering temperature.
 - b. Chilled-water leaving temperature.
 - c. Chilled-water flow rate.
 - d. Chilled-water inlet and outlet pressures.
 - e. Evaporator refrigerant pressure and temperature.
 - f. Condenser refrigerant pressure and liquid temperature.
 - g. Condenser-water entering temperature.
 - h. Condenser-water leaving temperature.
 - i. Condenser-water flow rate.
 - j. Refrigerant levels.
 - k. Oil pressure and temperature.
 - l. Oil level.
 - m. Compressor refrigerant discharge temperature.
 - n. Compressor refrigerant suction temperature.
 - o. Addition of refrigerant.
 - p. Addition of oil.
 - q. Vibration levels or observation that vibration is not excessive.
 - r. Motor amperes per phase.
 - s. Motor volts per phase.
 - t. Refrigerant monitor level (PPM).
 - u. Purge exhaust time or discharge count.
 - v. Ambient temperature (dry bulb and wet bulb).
 - w. Date and time logged.

K. Utility Reports: Prepare Project-specific reports.

1. Electric Report:

- a. Include weekly report showing daily electrical consumption and peak electrical demand with time and date stamp for each meter.
- b. Include monthly report showing the daily electrical consumption and peak electrical demand with time and date stamp for each meter.
- c. Include annual report showing the monthly electrical consumption and peak electrical demand with time and date stamp for each meter.
- d. For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as lighting, receptacles and HVAC equipment showing daily electrical consumption and peak electrical demand.
- e. For each weekly, monthly and annual report, include sum total of all submeters in building showing electrical consumption and peak electrical demand.

2. Natural Gas Report:

- a. Include weekly report showing daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.
- b. Include monthly report showing the daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.
- c. Include annual report showing the monthly natural gas consumption and peak natural gas demand with time and date stamp for each meter.
- d. For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as boilers and service water heaters showing daily natural gas consumption and peak natural gas demand.
- e. For each weekly, monthly and annual report, include sum total of all submeters in building showing natural gas consumption and peak natural gas demand.

3. Service Water Report:

- a. Include weekly report showing daily service water consumption and peak service water demand with time and date stamp for each meter.
- b. Include monthly report showing the daily service water consumption and peak service water demand with time and date stamp for each meter.
- c. Include annual report showing the monthly service water consumption and peak service water demand with time and date stamp for each meter.
- d. For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as cooling tower makeup and irrigation showing daily service water consumption and peak service water demand.
- e. For each weekly, monthly and annual report, include sum total of all submeters in building showing service water consumption and peak service water demand.

L. Energy Reports: Prepare Project-specific daily, weekly, monthly , annual and since-installed energy reports.

1. Prepare report for each purchased energy utility, indicating the following:

- a. Time period being reported with beginning and end date, and time indicated.
- b. Consumption in units of measure commonly used to report specific utility consumption over time.
- c. Gross area served by utility.
- d. Consumption per unit area served using utility-specific unit of measure.
- e. Cost per utility unit.

- f. Utility cost per unit area.
 - g. Convert all utilities to a common energy consumption unit of measure and report for each utility.
 - h. Consumption per unit area using common unit of measure.
- 2. Prepare report for each renewable energy source, indicating the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Harvested energy in units of measure commonly used to report specific harvested energy consumption over time.
 - c. Gross area served by renewable energy source.
 - d. Harvested energy per unit area served using specific unit of measure.
 - e. Cost per purchased utility unit displaced by renewable energy.
 - f. Cost savings attributed to harvested energy source.
 - g. Cost savings per unit area attributed to harvested energy.
 - h. Convert all renewable energy sources to a common energy consumption unit of measure and report for each.
 - i. Harvested energy per unit area using common unit of measure.
- 3. Prepare purchased energy utility report for each submetered area that indicates the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Gross area served.
 - c. Energy consumption by energy utility type.
 - d. Energy consumption per unit area by energy utility type.
 - e. Total energy consumption of all utilities in common units of measure.
 - f. Total energy consumption of all utilities in common units of measure per unit area.
 - g. Unit energy cost by energy utility type.
 - h. Energy cost by energy utility type.
 - i. Energy cost per unit area by energy utility type.
 - j. Total cost of all energy utilities.
 - k. Total cost of all energy utilities per unit area.
- 4. Prepare Project total purchased energy utility report that combines all purchased energy utilities and all areas served. Project total energy report shall indicate the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Gross area served.
 - c. Energy consumption by energy utility type.
 - d. Energy consumption per unit area by energy utility type.
 - e. Total energy consumption of all utilities in common units of measure.
 - f. Total energy consumption of all utilities in common units of measure per unit area.
 - g. Unit energy cost by energy utility type.
 - h. Energy cost by energy utility type.
 - i. Energy cost per unit area by energy utility type.
 - j. Total cost of all energy utilities.
 - k. Total cost of all energy utilities per unit area.
- M. HVAC System Efficiency Reports: Prepare Project-specific daily weekly monthly , annual and since-installed HVAC system efficiency reports.
 - 1. Prepare report for each chilled-water system, indicating the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Cooling energy supplied during time period.

- c. Power energy consumed during time period by cooling equipment used to produce cooling energy supplied. List power consumed for each individual piece of equipment in system and summed total of all equipment in system.
 - d. Energy efficiency coefficient of performance determined by dividing power energy consumed into cooling energy supplied.
 - e. Energy efficiency determined by dividing cooling energy supplied into power energy consumed.
 - f. Units of measure used in report shall be consistent with units indicated for system.
2. Prepare report for each hot-water system, indicating the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Cooling energy supplied during time period.
 - c. Fuel consumed during time period by boilers used to produce heating energy supplied. List fuel consumed for each individual piece of equipment in system and summed total of all equipment in system.
 - d. Energy efficiency determined by dividing heating energy supplied into fuel energy consumed.
 - e. Units of measure used in report shall be consistent with units indicated for system.
3. Prepare report for each steam system, indicating the following:
 - a. Time period being reported with beginning and end date, and time indicated.
 - b. Cooling energy supplied during time period.
 - c. Fuel consumed during time period by boilers used to produce heating energy supplied. List fuel consumed for each individual piece of equipment in system and summed total of all equipment in system.
 - d. Energy efficiency determined by dividing heating energy supplied into fuel energy consumed.
 - e. Units of measure used in report shall be consistent with units indicated for system.

N. Weather Reports:

1. Include daily report showing the following:
 - a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Daily minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each day calculated from a base temperature of 55 deg F.
 - e. Number of cooling degree-days for each day calculated from a base temperature of 65 deg F.
 - f. Daily minimum, maximum, and average outdoor carbon dioxide level.
 - g. Daily minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.
2. Include weekly report showing the following:
 - a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Daily minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each day calculated from a base temperature of 55 deg F.
 - e. Number of cooling degree-days for each day calculated from a base temperature of 65 deg F.
 - f. Weekly minimum, maximum, and average outdoor carbon dioxide level.
 - g. Daily minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.

- i. Daily minimum, maximum, and average wind speed and direction.
 3. Include monthly report showing the following:
 - a. Daily minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Daily minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Daily minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each day calculated from a base temperature of 55 deg F.
 - e. Number of cooling degree-days for each day calculated from a base temperature of 65 deg F.
 - f. Monthly minimum, maximum, and average outdoor carbon dioxide level.
 - g. Daily minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.
 4. Include annual (12-month) report showing the following:
 - a. Monthly minimum, maximum, and average outdoor dry-bulb temperature.
 - b. Monthly minimum, maximum, and average outdoor wet-bulb temperature.
 - c. Monthly minimum, maximum, and average outdoor dew point temperature.
 - d. Number of heating degree-days for each month calculated from a base temperature of 55 deg F.
 - e. Number of cooling degree-days for each month calculated from a base temperature of 65 deg F.
 - f. Annual minimum, maximum, and average outdoor carbon dioxide level.
 - g. Monthly minimum, maximum, and average relative humidity.
 - h. Daily minimum, maximum, and average barometric pressure.
 - i. Daily minimum, maximum, and average wind speed and direction.
- O. Standard Trends:
 1. Trend all I/O point present values, set points, and other parameters indicated for trending.
 2. Trends shall be associated into groups, and a trend report shall be set up for each group.
 3. Trends shall be stored within DDC controller and uploaded to hard drives automatically on reaching 75 of DDC controller buffer limit, or by operator request, or by archiving time schedule.
 4. Preset trend intervals for each I/O point after review with Owner.
 5. Trend intervals shall be operator selectable from 10 seconds up to 60 minutes. Minimum number of consecutive trend values stored at one time shall be 100 per variable.
 6. When drive storage memory is full, most recent data shall overwrite oldest data.
 7. Archived and real-time trend data shall be available for viewing numerically and graphically by operators.
- P. Custom Trends: Operator shall be able to define a custom trend log for any I/O point in DDC system.
 1. Each trend shall include interval, start time, and stop time.
 2. Data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on server hard drives.
 3. Data shall be retrievable for use in spreadsheets and standard database programs.
- Q. Programming Software:
 1. Include programming software to execute sequences of operation indicated.
 2. Include programming routines in simple and easy to follow logic with detailed text comments describing what the logic does and how it corresponds to sequence of operation.

3. Programming software shall be as follows :
 - a. Graphic Based: Programming shall use a library of function blocks made from preprogrammed code designed for DDC control systems.
 - 1) Function blocks shall be assembled with interconnection lines that represent to control sequence in a flowchart.
 - 2) Programming tools shall be viewable in real time to show present values and logical results of each function block.
 - b. Menu Based: Programming shall be done by entering parameters, definitions, conditions, requirements and constraints.
 - c. Line by Line and Text Based: Programming shall declare variable types such as local, global, real, integer, and so on, at the beginning of the program. Use descriptive comments frequently to describe programming code.
4. Include means for detecting programming errors and testing software control strategies with a simulation tool before implementing in actual control. Simulation tool may be inherent with programming software or as a separate product.

R. Database Management Software:

1. Where a separate SQL database is used for information storage, DDC system shall include database management software that separates database monitoring and managing functions by supporting multiple separate windows.
2. Database secure access shall be accomplished using standard SQL authentication including ability to access data for use outside of DDC system applications.
3. Database management function shall include summarized information on trend, alarm, event, and audit for the following database management actions:
 - a. Backup.
 - b. Purge.
 - c. Restore.
4. Database management software shall support the following:
 - a. Statistics: Display database server information and trend, alarm, event, and audit information on database.
 - b. Maintenance: Include method of purging records from trend, alarm, event and audit databases by supporting separate screens for creating a backup before purging, selecting database, and allowing for retention of a selected number of day's data.
 - c. Backup: Include means to create a database backup file and select a storage location.
 - d. Restore: Include a restricted means of restoring a database by requiring operator to have proper security level.
5. Database management software shall include information of current database activity, including the following:
 - a. Ready.
 - b. Purging record from a database.
 - c. Action failed.
 - d. Refreshing statistics.
 - e. Restoring database.
 - f. Shrinking a database.
 - g. Backing up a database.

- h. Resetting Internet information services.
 - i. Starting network device manager.
 - j. Shutting down the network device manager.
 - k. Action successful.
- 6. Database management software monitoring functions shall continuously read database information once operator has logged on.
- 7. Include operator notification through on-screen pop-up display and e-mail message when database value has exceeded a warning or alarm limit.
- 8. Monitoring settings window shall have the following sections:
 - a. Allow operator to set and review scan intervals and start times.
 - b. E-mail: Allow operator to create and review e-mail and phone text messages to be delivered when a warning or an alarm is generated.
 - c. Warning: Allow operator to define warning limit parameters, set reminder frequency and link e-mail message.
 - d. Alarm: Allow operator to define alarm limit parameters, set reminder frequency and link e-mail message.
 - e. Database Login: Protect system from unauthorized database manipulation by creating a read access and a write access for each of trend, alarm, event and audit databases as well as operator proper security access to restore a database.
- 9. Monitoring settings taskbar shall include the following informational icons:
 - a. Normal: Indicates by color and size, or other easily identifiable means that all databases are within their limits.
 - b. Warning: Indicates by color and size, or other easily identifiable means that one or more databases have exceeded their warning limit.
 - c. Alarm: Indicates by color and size, or other easily identifiable means that one or more databases have exceeded their alarm limit.

2.11 ASHRAE 135 GATEWAYS

- A. Include BACnet communication ports, whenever available as an equipment OEM standard option, for integration via a single communication cable. BACnet-controlled plant equipment includes, but is not limited to, boilers, chillers, and variable-speed drives.
- B. Include gateways to connect BACnet to legacy systems, existing non-BACnet devices, and existing non-BACnet DDC-controlled equipment, only when specifically requested and approved by Owner.
- C. Include with each gateway an interoperability schedule showing each point or event on legacy side that BACnet "client" will read, and each parameter that BACnet network will write to. Describe this interoperability of BACnet services, or BIBBs, defined in ASHRAE 135, Annex K.
- D. Gateway Minimum Requirements:
 - 1. Read and view all readable object properties on non-BACnet network to BACnet network and vice versa where applicable.
 - 2. Write to all writeable object properties on non-BACnet network from BACnet network and vice versa where applicable.
 - 3. Include single-pass (only one protocol to BACnet without intermediary protocols) translation from non-BACnet protocol to BACnet and vice versa.

4. Comply with requirements of Data Sharing Read Property, Data Sharing Write Property, Device Management Dynamic Device Binding-B, and Device Management Communication Control BIBBs according to ASHRAE 135.
5. Hardware, software, software licenses, and configuration tools for operator-to-gateway communications.
6. Backup programming and parameters on CD media and the ability to modify, download, backup, and restore gateway configuration.

2.12 ASHRAE 135 PROTOCOL ANALYZER

- A. Analyzer and required cables and fittings for connection to ASHRAE 135 network.
- B. Analyzer shall include the following minimum capabilities:
 1. Capture and store to a file data traffic on all network levels.
 2. Measure bandwidth usage.
 3. Filtering options with ability to ignore select traffic.

2.13 DDC CONTROLLERS

- A. DDC system shall consist of a combination of network controllers, programmable application controllers and application-specific controllers to satisfy performance requirements indicated.
 1. All controllers on project shall be IP based with a direct connection from each controller to a managed network switch port. BACnet MS/TP shall only be used where the equipment, VFD etc. does not support an IP connection.
 2. Unmanaged network switches shall not be used anywhere on the control system without explicit approval in writing from the engineer of record.
- B. DDC controllers shall perform monitoring, control, energy optimization and other requirements indicated.
- C. DDC controllers shall use a multitasking, multiuser, real-time digital control microprocessor with a distributed network database and intelligence.
- D. Each DDC controller shall be capable of full and complete operation as a completely independent unit and as a part of a DDC system wide distributed network.
- E. Environment Requirements:
 1. Controller hardware shall be suitable for the anticipated ambient conditions.
 2. Controllers located in conditioned space shall be rated for operation at 32 to 120 deg F.
 3. Controllers located outdoors shall be rated for operation at 40 to 150 deg F.
- F. Power and Noise Immunity:
 1. Controller shall operate at 90 to 110 percent of nominal voltage rating and shall perform an orderly shutdown below 80 percent of nominal voltage.
 2. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios with up to 5 W of power located within 36 inches of enclosure.

G. DDC Controller Spare Processing Capacity:

1. Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:
 - a. Network Controllers: 50 percent.
 - b. Programmable Application Controllers: Not less than 60 percent.
 - c. Application-Specific Controllers: Not less than 70 percent.
2. Memory shall support DDC controller's operating system and database and shall include the following:
 - a. Monitoring and control.
 - b. Energy management, operation and optimization applications.
 - c. Alarm management.
 - d. Historical trend data of all connected I/O points.
 - e. Maintenance applications.
 - f. Operator interfaces.
 - g. Monitoring of manual overrides.

H. DDC Controller Spare I/O Point Capacity: Include spare I/O point capacity for each controller as follows:

1. Network Controllers:
 - a. 20 percent of each AI, AO, BI, and BO point connected to controller.
 - b. Minimum Spare I/O Points per Controller:
 - 1) AIs: Three.
 - 2) AOs: Three.
 - 3) BIs: Three.
 - 4) BOs: Three.
2. Programmable Application Controllers:
 - a. 20 percent of each AI, AO, BI, and BO point connected to controller.
 - b. Minimum Spare I/O Points per Controller:
 - 1) AIs: Three.
 - 2) AOs: Three.
 - 3) BIs: Three.
 - 4) BOs: Three.
3. Application-Specific Controllers:
 - a. 10 percent of each AI, AO, BI, and BO point connected to controller.
 - b. Minimum Spare I/O Points per Controller:
 - 1) AIs: Two.
 - 2) AOs: Two.
 - 3) BIs: One.
 - 4) BOs: One.

- I. Maintenance and Support: Include the following features to facilitate maintenance and support:
 1. Mount microprocessor components on circuit cards for ease of removal and replacement.
 2. Means to quickly and easily disconnect controller from network.
 3. Means to quickly and easily access connect to field test equipment.
 4. Visual indication that controller electric power is on, of communication fault or trouble, and that controller is receiving and sending signals to network.
- J. Input and Output Point Interface:
 1. Hardwired input and output points shall connect to network, programmable application and application-specific controllers.
 2. Input and output points shall be protected so shorting of point to itself, to another point, or to ground will not damage controller.
 3. Input and output points shall be protected from voltage up to 24 V of any duration so that contact will not damage controller.
 4. AIs:
 - a. AIs shall include monitoring of low-voltage (zero- to 10-V dc), current (4 to 20 mA) and resistance signals from thermistor and RTD sensors.
 - b. AIs shall be compatible with, and field configurable to, sensor and transmitters installed.
 - c. Controller AIs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of 16 bits or better to comply with accuracy requirements indicated.
 - d. Signal conditioning including transient rejection shall be provided for each AI.
 - e. Capable of being individually calibrated for zero and span.
 - f. Incorporate common-mode noise rejection of at least 50 dB from zero to 100 Hz for differential inputs, and normal-mode noise rejection of at least 20 dB at 60 Hz from a source impedance of 10000 ohms.
 5. AOs:
 - a. Controller AOs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of 16 bits or better to comply with accuracy requirements indicated.
 - b. Output signals shall have a range of 4 to 20 mA dc or zero- to 10-V dc as required to include proper control of output device.
 - c. Capable of being individually calibrated for zero and span.
 - d. AOs shall not exhibit a drift of greater than 0.4 percent of range per year.
 6. BIs:
 - a. Controller BIs shall accept contact closures and shall ignore transients of less than 5-ms duration.
 - b. Isolation and protection against an applied steady-state voltage of up to 180-V ac peak.
 - c. BIs shall include a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against effects of contact bounce and noise.
 - d. BIs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.
 - e. Pulse accumulation input points shall comply with all requirements of BIs and accept up to 10 pulses per second for pulse accumulation. Buffer shall be provided to totalize pulses. Pulse accumulator shall accept rates of at least 20 pulses per second. The totalized value shall be reset to zero on operator's command.

7. BOs:
- a. Controller BOs shall include relay contact closures or triac outputs for momentary and maintained operation of output devices.
 - 1) Relay contact closures shall have a minimum duration of 0.1 second. Relays shall include at least 180 V of isolation. Electromagnetic interference suppression shall be provided on all output lines to limit transients to non-damaging levels. Minimum contact rating shall be 1 A at 24-V ac.
 - 2) Triac outputs shall include at least 180 V of isolation. Minimum contact rating shall be 1 A at 24-V ac.
 - b. BOs shall include for two-state operation or a pulsed low-voltage signal for pulse-width modulation control.
 - c. BOs shall be selectable for either normally open or normally closed operation.
 - d. Include tristate outputs (two coordinated BOs) for control of three-point floating-type electronic actuators without feedback.
 - e. Limit use of three-point floating devices to VAV terminal unit control applications. Control algorithms shall operate actuator to one end of its stroke once every 24 hours for verification of operator tracking.

2.14 NETWORK CONTROLLERS

A. General Network Controller Requirements:

- 1. Network Controllers shall be SNE type. Network Automation Engines (NAE) shall not be used.
- 2. Include adequate number of controllers to achieve performance indicated.
- 3. System shall consist of one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.
- 4. Controller shall have enough memory to support its operating system, database, and programming requirements.
- 5. Data shall be shared between networked controllers and other network devices.
- 6. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
- 7. Controllers that perform scheduling shall have a real-time clock.
- 8. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
- 9. Controllers shall be fully programmable.

B. Communication:

- 1. Network controllers shall communicate with other devices on DDC system Level one network.
- 2. Network controller also shall perform routing if connected to a network of programmable application and application-specific controllers.

C. Operator Interface:

- 1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation or mobile device.
- 2. Local Keypad and Display:
 - a. Equip controller with local keypad and digital display for interrogating and editing data.

- b. Use of keypad and display shall require security password.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least 96 hours.

2.15 PROGRAMMABLE APPLICATION CONTROLLERS

A. General Programmable Application Controller Requirements:

1. Include adequate number of controllers to achieve performance indicated.
2. Controller shall have enough memory to support its operating system, database, and programming requirements.
3. Data shall be shared between networked controllers and other network devices.
4. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
5. Controllers that perform scheduling shall have a real-time clock.
6. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
7. Controllers shall be fully programmable.

B. Communication:

1. Programmable application controllers shall communicate with other devices on network.

C. Operator Interface:

1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation or mobile device.
2. Local Keypad and Display:
 - a. Equip controller with local keypad and digital display for interrogating and editing data.
 - b. Use of keypad and display shall require security password.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

2.16 APPLICATION-SPECIFIC CONTROLLERS

- A. Description: Microprocessor-based controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment. Controllers are not fully user-programmable but are configurable and customizable for operation of equipment they are designed to control.
 - 1. Capable of standalone operation and shall continue to include control functions without being connected to network.
 - 2. Data shall be shared between networked controllers and other network devices.
- B. Communication: Application-specific controllers shall communicate with other application-specific controller and devices on network, and to programmable application and network controllers.
- C. Operator Interface: Controller shall be equipped with a service communications port for connection to a portable operator's workstation. Connection shall extend to port on space temperature sensor that is connected to controller.
- D. Serviceability:
 - 1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
 - 2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
 - 3. Controller shall use nonvolatile memory and maintain all BIOS and programming information in event of power loss.

2.17 CONTROLLER SOFTWARE

- A. General Controller Software Requirements:
 - 1. Software applications shall reside and operate in controllers. Editing of applications shall occur at operator workstations.
 - 2. I/O points shall be identified by up to 30 -character point name and up to 16 -character point descriptor. Same names shall be used at operator workstations.
 - 3. Control functions shall be executed within controllers using DDC algorithms.
 - 4. Controllers shall be configured to use stored default values to ensure fail-safe operation. Default values shall be used when there is a failure of a connected input instrument or loss of communication of a global point value.
- B. Security:
 - 1. Operator access shall be secured using individual security passwords and user names.
 - 2. Passwords shall restrict operator to points, applications, and system functions as assigned by system manager.
 - 3. Operator log-on and log-off attempts shall be recorded.
 - 4. System shall protect itself from unauthorized use by automatically logging off after last keystroke. The delay time shall be operator-definable.
- C. Scheduling: Include capability to schedule each point or group of points in system. Each schedule shall consist of the following:
 - 1. Weekly Schedule:
 - a. Include separate schedules for each day of week.

- b. Each schedule should include the capability for start, stop, optimal start, optimal stop, and night economizer.
 - c. Each schedule may consist of up to 10 events.
 - d. When a group of objects are scheduled together, include capability to adjust start and stop times for each member.
 - 2. Exception Schedules:
 - a. Include ability for operator to designate any day of the year as an exception schedule.
 - b. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by regular schedule for that day of week.
 - 3. Holiday Schedules:
 - a. Include capability for operator to define up to 99 special or holiday schedules.
 - b. Schedules may be placed on scheduling calendar and will be repeated each year.
 - c. Operator shall be able to define length of each holiday period.
- D. System Coordination:
 - 1. Include standard application for proper coordination of equipment.
 - 2. Application shall include operator with a method of grouping together equipment based on function and location.
 - 3. Group may then be used for scheduling and other applications.
- E. Binary Alarms:
 - 1. Each binary point shall be set to alarm based on operator-specified state.
 - 2. Include capability to automatically and manually disable alarming.
- F. Analog Alarms:
 - 1. Each analog object shall have both high and low alarm limits.
 - 2. Alarming shall be able to be automatically and manually disabled.
- G. Alarm Reporting:
 - 1. Operator shall be able to determine action to be taken in event of an alarm.
 - 2. Alarms shall be routed to appropriate operator workstations based on time and other conditions.
 - 3. Alarm shall be able to start programs, print, be logged in event log, generate custom messages, and display graphics.
- H. Remote Communication:
 - 1. System shall have ability to dial out in the event of an alarm.
- I. Electric Power Demand Limiting:
 - 1. Demand-limiting program shall monitor building or other operator-defined electric power consumption from signals connected to electric power meter or from a watt transducer or current transformer.
 - 2. Demand-limiting program shall predict probable power demand such that action can be taken to prevent exceeding demand limit. When demand prediction exceeds demand limit, action will be taken to reduce loads in a predetermined manner. When demand prediction indicates demand limit will not be exceeded, action will be taken to restore loads in a predetermined manner.

3. Demand reduction shall be accomplished by the following means:
 - a. Reset air-handling unit supply temperature set points.
 - b. Reset space temperature set points.
 - c. De-energize equipment based on priority.
4. Demand-limiting parameters, frequency of calculations, time intervals, and other relevant variables shall be based on the means by which electric power service provider computes demand charges.
5. Include demand-limiting prediction and control for any individual meter monitored by system or for total of any combination of meters.
6. Include means operator to make the following changes online:
 - a. Addition and deletion of loads controlled.
 - b. Changes in demand intervals.
 - c. Changes in demand limit for meter(s).
 - d. Maximum shutoff time for equipment.
 - e. Minimum shutoff time for equipment.
 - f. Select rotational or sequential shedding and restoring.
 - g. Shed and restore priority.
7. Include the following information and reports, to be available on an hourly, daily, weekly, monthly and annual basis:
 - a. Total electric consumption.
 - b. Peak demand.
 - c. Date and time of peak demand.
 - d. Daily peak demand.
- J. Maintenance Management: System shall monitor equipment status and generate maintenance messages based on operator-designated run-time, starts, and calendar date limits.
- K. Sequencing: Include application software based on sequences of operation indicated to properly sequence chillers, boilers, and other applicable HVAC equipment.
- L. Control Loops:
 1. Support any of the following control loops, as applicable to control required:
 - a. Two-position (on/off, open/close, slow/fast) control.
 - b. Proportional control.
 - c. Proportional plus integral (PI) control.
 - d. Proportional plus integral plus derivative (PID) control.
 - 1) Include PID algorithms with direct or reverse action and anti-windup.
 - 2) Algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs.
 - 3) Controlled variable, set point, and PID gains shall be operator-selectable.
 - e. Adaptive (automatic tuning).
- M. Staggered Start: Application shall prevent all controlled equipment from simultaneously restarting after a power outage. Order which equipment (or groups of equipment) is started, along with the time delay between starts, shall be operator-selectable.

N. Energy Calculations:

1. Include software to allow instantaneous power or flow rates to be accumulated and converted to energy usage data.
2. Include an algorithm that calculates a sliding-window average (rolling average). Algorithm shall be flexible to allow window intervals to be operator specified (such as 15, 30, or 60 minutes).
3. Include an algorithm that calculates a fixed-window average. A digital input signal shall define start of window period (such as signal from utility meter) to synchronize fixed-window average with that used by utility.

O. Anti-Short Cycling:

1. BO points shall be protected from short cycling.
2. Feature shall allow minimum on-time and off-time to be selected.

P. On and Off Control with Differential:

1. Include an algorithm that allows a BO to be cycled based on a controlled variable and set point.
2. Algorithm shall be direct- or reverse-acting and incorporate an adjustable differential.

Q. Run-Time Totalization:

1. Include software to totalize run-times for all BI and BO points.
2. A high run-time alarm shall be assigned, if required, by operator.

2.18 ENCLOSURES

A. General Enclosure Requirements:

1. House each controller and associated control accessories in a single enclosure. Enclosure shall serve as central tie-in point for control devices such as switches, transmitters, transducers, power supplies and transformers.
2. Do not house more than one controller in a single enclosure.
3. Include enclosure door with key locking mechanism. Key locks alike for all enclosures and include one pair of keys per enclosure.
4. Equip doors of enclosures housing controllers and components with analog or digital displays with windows to allow visual observation of displays without opening enclosure door.
5. Individual wall-mounted single-door enclosures shall not exceed 36 inches wide and 48 inches high.
6. Individual wall-mounted double-door enclosures shall not exceed 60 inches wide and 36 inches high.
7. Freestanding enclosures shall not exceed 48 inches wide and 72 inches high.
8. Include wall-mounted enclosures with brackets suitable for mounting enclosures to wall or freestanding support stand as indicated.
9. Supply each enclosure with a complete set of as-built schematics, tubing, and wiring diagrams and product literature located in a pocket on inside of door. For enclosures with windows, include pocket on bottom of enclosure.

B. Internal Arrangement:

1. Internal layout of enclosure shall group and protect pneumatic, electric, and electronic components associated with a controller, but not an integral part of controller.
2. Arrange layout to group similar products together.
3. Include a barrier between line-voltage and low-voltage electrical and electronic products.

4. Factory or shop install products, tubing, cabling and wiring complying with requirements and standards indicated.
5. Terminate field cable and wire using heavy-duty terminal blocks.
6. Include spare terminals, equal to not less than 10 percent of used terminals.
7. Include spade lugs for stranded cable and wire.
8. Install a maximum of two wires on each side of a terminal.
9. Include enclosure field power supply with a toggle-type switch located at entrance inside enclosure to disconnect power.
10. Include enclosure with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with a 5-A circuit breaker.
11. Mount products within enclosure on removable internal panel(s).
12. Include products mounted in enclosures with engraved, laminated phenolic nameplates (black letters on a white background). The nameplates shall have at least 1/4-inch- high lettering.
13. Route tubing cable and wire located inside enclosure within a raceway with a continuous removable cover.
14. Label each end of cable, wire and tubing in enclosure following an approved identification system that extends from field I/O connection and all intermediate connections throughout length to controller connection.
15. Size enclosure internal panel to include at least 25 percent spare area on face of panel.

C. Environmental Requirements:

1. Evaluate temperature and humidity requirements of each product to be installed within each enclosure.
2. Calculate enclosure internal operating temperature considering heat dissipation of all products installed within enclosure and ambient effects (solar, conduction and wind) on enclosure.
3. Where required by application, include temperature-controlled electrical heat to maintain inside of enclosure above minimum operating temperature of product with most stringent requirement.
4. Where required by application, include temperature-controlled ventilation fans with filtered louver(s) to maintain inside of enclosure below maximum operating temperature of product with most stringent requirement.
5. Include temperature-controlled cooling within the enclosure for applications where ventilation fans cannot maintain inside temperature of enclosure below maximum operating temperature of product with most stringent requirement.
6. Where required by application, include humidity-controlled electric dehumidifier or cooling to maintain inside of enclosure below maximum relative humidity of product with most stringent requirement and to prevent surface condensation within enclosure.

D. Wall-Mounted, NEMA 250, Type 1:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Hammond Mfg. Co. Inc.
 - b. Hoffman; brand of nVent Electrical plc.
 - c. Saginaw Control and Engineering.
2. Enclosure shall be NRTL listed according to UL 50 or UL 50E.
3. Construct enclosure of steel, not less than:
 - a. Enclosure size less than 24 in.: 0.067 in. thick.
 - b. Enclosure size 24 in. and larger: 0.093 in. thick.

4. Finish enclosure inside and out with polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 - a. Exterior color shall be ANSI 61 gray.
 - b. Interior color shall be ANSI 61 gray.
5. Hinged door full size of front face of enclosure and supported using:
 - a. Enclosures sizes less than 36 in. tall: Multiple butt hinges.
 - b. Enclosures sizes 36 in. tall and larger: Continuous piano hinges.
6. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 - a. Size less than 24 in.: Solid steel, 0.053 in. thick.
 - b. Size 24 in. and larger: Solid steel, 0.093 in. thick.
7. Internal panel mounting hardware, grounding hardware and sealing washers.
8. Grounding stud on enclosure body.
9. Thermoplastic pocket on inside of door for record Drawings and Product Data.

E. Accessories:

1. Framed Fixed Window Kit for NEMA 250, Types 4, 4X, and 12 Enclosures:
 - a. 0.25-inch- thick, scratch-resistant acrylic or polycarbonate window mounted in a metal frame matching adjacent door material.
 - b. Enclosure types, except NEMA 250 Type 1, shall have a continuous gasket material around perimeter of window and frame to provide watertight seal.
 - c. Window kit shall be factory or shop installed before shipment to Project.
2. Frameless Fixed Window Kit for NEMA 250, Type 1 Enclosures:
 - a. 0.125-inch- thick, polycarbonate window mounted in enclosure door material.
 - b. Window attached to door with screw fasteners and continuous strip of high-strength double-sided tape around window perimeter.
 - c. Window kit shall be factory or shop installed before shipment to Project.
3. Frame Fixed or Hinged Window Kit for NEMA 250, Types 1 and 12 Enclosures:
 - a. 0.25-inch- thick, scratch-resistant acrylic or polycarbonate window mounted in a metal frame matching adjacent door material.
 - b. Enclosure types, except NEMA 250 Type 1, shall have a continuous gasket material around perimeter of window and frame to provide watertight seal.
 - c. Window kit shall be factory or shop installed before shipment to Project.
4. Bar handle with keyed cylinder lock set.

2.19 RELAYS

A. General-Purpose Relays:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Functional Devices. Inc.
 - b. IDEC.
2. Relays shall be heavy duty and rated for at least 10 A at 250-V ac and 60 Hz.
3. Relays shall be either double pole double throw (DPDT) or three-pole double throw, depending on the control application.
4. Use a plug-in-style relay with an eight-pin octal plug for DPDT relays and an 11-pin octal plug for three-pole double-throw relays.
5. Construct the contacts of either silver cadmium oxide or gold.
6. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
7. Relays shall have LED indication and a manual reset and push-to-test button.
8. Performance:
 - a. Mechanical Life: At least 10 million cycles.
 - b. Electrical Life: At least 100,000 cycles at rated load.
 - c. Pickup Time: 15 ms or less.
 - d. Dropout Time: 10 ms or less.
 - e. Pull-in Voltage: 85 percent of rated voltage.
 - f. Dropout Voltage: 50 percent of nominal rated voltage.
 - g. Power Consumption: 2 VA.
 - h. Ambient Operating Temperatures: Minus 40 to 115 deg F.
9. Equip relays with coil transient suppression to limit transients to non-damaging levels.
10. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
11. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

B. Multifunction Time-Delay Relays:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Functional Devices. Inc.
 - b. IDEC.
2. Relays shall be continuous duty and rated for at least 10 A at 240-V ac and 60 Hz.
3. Relays shall be DPDT relay with up to eight programmable functions to provide on/off delay, interval and recycle timing functions.
4. Use a plug-in-style relay with either an 8- or 11-pin octal plug.
5. Construct the contacts of either silver cadmium oxide or gold.
6. Enclose the relay in a dust-tight cover.
7. Include knob and dial scale for setting delay time.
8. Performance:
 - a. Mechanical Life: At least 10 million cycles.
 - b. Electrical Life: At least 100,000 cycles at rated load.
 - c. Timing Ranges: Multiple ranges from 0.1 seconds to 100 minutes.
 - d. Repeatability: Within 2 percent.
 - e. Recycle Time: 45 ms.

- f. Minimum Pulse Width Control: 50 ms.
 - g. Power Consumption: 5 VA or less at 120-V ac.
 - h. Ambient Operating Temperatures: Minus 40 to 115 deg F.
- 9. Equip relays with coil transient suppression to limit transients to non-damaging levels.
- 10. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
- 11. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

C. Latching Relays:

- 1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Functional Devices. Inc.
 - b. IDEC.
- 2. Relays shall be continuous duty and rated for at least 10 A at 250-V ac and 60 Hz.
- 3. Relays shall be either DPDT or three-pole double throw, depending on the control application.
- 4. Use a plug-in-style relay with a multibladed plug.
- 5. Construct the contacts of either silver cadmium oxide or gold.
- 6. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
- 7. Performance:
 - a. Mechanical Life: At least 10 million cycles.
 - b. Electrical Life: At least 100,000 cycles at rated load.
 - c. Pickup Time: 15 ms or less.
 - d. Dropout Time: 10 ms or less.
 - e. Pull-in Voltage: 85 percent of rated voltage.
 - f. Dropout Voltage: 50 percent of nominal rated voltage.
 - g. Power Consumption: 2 VA.
 - h. Ambient Operating Temperatures: Minus 40 to 115 deg F.
- 8. Equip relays with coil transient suppression to limit transients to non-damaging levels.
- 9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
- 10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

D. Current Sensing Relay:

- 1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Functional Devices. Inc.
 - b. Veris Industries.
- 2. Monitors ac current.
- 3. Independent adjustable controls for pickup and dropout current.
- 4. Energized when supply voltage is present and current is above pickup setting.
- 5. De-energizes when monitored current is below dropout current.
- 6. Dropout current is adjustable from 50 to 95 percent of pickup current.
- 7. Include a current transformer, if required for application.
- 8. House current sensing relay and current transformer in its own enclosure. Use NEMA 250, Type 12 enclosure for indoors and NEMA 250, Type 4 for outdoors.

E. Combination On-Off Status Sensor and On-Off Relay:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Functional Devices Inc.
 - b. Veris Industries.
2. Description:
 - a. On-off control and status indication in a single device.
 - b. LED status indication of activated relay and current trigger.
 - c. Closed-Open-Auto override switch located on the load side of the relay.
3. Performance:
 - a. Ambient Temperature: Minus 30 to 140 deg F.
 - b. Voltage Rating: Single-phase loads rated for 300-V ac. Three-phase loads rated for 600-V ac.
4. Status Indication:
 - a. Current Sensor: Integral sensing for single-phase loads up to 20 A and external solid or split sensing ring for three-phase loads up to 150 A.
 - b. Current Sensor Range: As required by application.
 - c. Current Set Point: Adjustable.
 - d. Current Sensor Output:
 - 1) Solid-state, single-pole double-throw contact rated for 30-V ac and dc and for 0.4 A.
 - 2) Solid-state, single-pole double-throw contact rated for 120-V ac and 1.0 A.
 - 3) Analog, zero- to 5- or 10-V dc.
 - 4) Analog, 4 to 20 mA, loop powered.
5. Relay: Single-pole double-throw, continuous-duty coil; rated for 10-million mechanical cycles.
6. Enclosure: NEMA 250, Type 1 enclosure.

2.20 ELECTRICAL POWER DEVICES

A. Transformers:

1. Transformer shall be sized for the total connected load, plus an additional 25 percent of connected load.
2. Transformer shall be at least 100 VA.
3. Transformer shall have both primary and secondary fuses.

B. Power-Line Conditioner:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. SOLA HD.
2. General Power-Line Conditioner Requirements:
 - a. Design to ensure maximum reliability, serviceability and performance.

- b. Overall function of the power-line conditioner is to receive raw, polluted electrical power and purify it for use by electronic equipment. The power-line conditioner shall provide isolated, regulated, transient, and noise-free sinusoidal power to loads served.
- 3. Standards: NRTL listed per UL 1012.
- 4. Performance:
 - a. Single phase, continuous, 100 percent duty rated KVA/KW capacity. Design to supply power for linear or nonlinear, high crest factor, resistive and reactive loads.
 - b. Automatically regulate output voltage to within 2 percent or better with input voltage fluctuations of plus 10 to minus 20 percent of nominal when system is loaded 100 percent. Use Variable Range Regulation to obtain improved line voltage regulation when operating under less than full load conditions.
 - 1) At 75 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 35 percent of nominal.
 - 2) At 50 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 40 percent of nominal.
 - 3) At 25 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 45 percent of nominal.
 - c. With input voltage distortion of up to 40 percent, limit the output voltage sine wave to a maximum harmonic content of 5 percent.
 - d. Automatically regulate output voltage to within 2.5 percent when load (resistive) changes from zero percent to 100 percent to zero percent.
 - e. Output voltage returns to 95 percent of nominal level within two cycles and to 100 percent within three cycles when the output is taken from no load to full resistive load or vice-versa. Recovery from partial resistive load changes is corrected in a shorter period of time.
 - f. K Factor: 30, designed to operate with nonlinear, non-sinusoidal, high crest factor loads without overheating.
 - g. Input power factor within 0.95 approaching unity with load power factor as poor as 0.6.
 - h. Attenuate load-generated odd current harmonics 23 dB at the input.
 - i. Electrically isolate the primary from the secondary. Meet isolation criteria as defined in NFPA 70, Article 250-5D.
 - j. Lighting and Surge Protection: Compares to UL 1449 rating of 330 V when subjected to Category B3 (6000 V/3000 A) combination waveform as established by IEEE C62.41.
 - k. Common-mode noise attenuation of 140 dB.
 - l. Transverse-mode noise attenuation of 120 dB.
 - m. With loss of input power for up to 16.6 ms, the output sine wave remains at usable ac voltage levels.
 - n. Reliability of 200,000 hours' MTBF.
 - o. At full load, when measured at 1-m distance, audible noise is not to exceed 54 dB.
 - p. Approximately 92 percent efficient at full load.
- 5. Transformer Construction:
 - a. Ferroresonant, dry type, convection cooled, 600V class. Transformer windings of Class H (220 deg C) insulated copper.
 - b. Use a Class H installation system throughout with operating temperatures not to exceed 150 deg C over a 40-deg C ambient temperature.
 - c. Configure transformer primary for multi-input voltage. Include input terminals for source conductors and ground.
 - d. Manufacture transformer core using M-6 grade, grain-oriented, stress-relieved transformer steel.

- e. Configure transformer secondary in a 240/120-V split with a 208-V tap or straight 120 V, depending on power output size.
 - f. Electrically isolate the transformer secondary windings from the primary windings. Bond neutral conductor to cabinet enclosure and output neutral terminal.
 - g. Include interface terminals for output power hot, neutral and ground conductors.
 - h. Label leads, wires and terminals to correspond with circuit wiring diagram.
 - i. Vacuum impregnate transformer with epoxy resin.
 - 6. Cabinet Construction:
 - a. Design for panel or floor mounting.
 - b. NEMA 250, Type 1, general-purpose, indoor enclosure.
 - c. Manufacture the cabinet from heavy gauge steel complying with UL 50.
 - d. Include a textured baked-on paint finish.
- C. Transient Voltage Suppression and High-Frequency Noise Filter Unit:
- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Current Technology Inc.
 - 2. The maximum continuous operating voltage shall be at least 125 percent.
 - 3. The operating frequency range shall be 47 to 63 Hz.
 - 4. Protection modes according to NEMA LS-1.
 - 5. The rated single-pulse surge current capacity, for each mode of protection, shall be no less than the following:
 - a. Line to Neutral: 45,000 A.
 - b. Neutral to Ground: 45,000 A.
 - c. Line to Ground: 45,000 A.
 - d. Per Phase: 90,000 A.
 - 6. Clamping voltages shall be in compliance with test and evaluation procedures defined in NEMA LS-1.
 - 1. Maximum clamping voltage shall be as follows:
 - a. Line to Neutral: 360 V.
 - b. Line to Ground: 360 V.
 - c. Neutral to Ground: 360 V.
 - 7. Electromagnetic interference and RF interference noise rejection or attenuation values shall comply with test and evaluation procedures defined in NEMA LS-1.
 - a. Line to Neutral:
 - 1) 100 kHz: 42 dB.
 - 2) 1 MHz: 25 dB.
 - 3) 10 MHz: 21 dB.
 - 4) 100 MHz: 36 dB.
 - b. Line to Ground:
 - 1) 100 kHz: 16 dB.
 - 2) 1 MHz: 55 dB.
 - 3) 10 MHz: 81 dB.

4) 100 MHz: 80 dB.

8. Unit shall have LED status indicator that extinguishes to indicate a failure.
9. Unit shall be listed by an NRTL as a transient voltage surge suppressor per UL 1449, and as an electromagnetic interference filter per UL 1283.
10. Unit shall not generate any appreciable magnetic field.
11. Unit shall not generate an audible noise.

D. DC Power Supply:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Functional Devices, Inc.
 - b. IDEC.
2. Plug-in style suitable for mating with a standard eight-pin octal socket. Include the power supply with a mating mounting socket.
3. Enclose circuitry in a housing.
4. Include both line and load regulation to ensure a stable output. To protect both the power supply and the load, power supply shall have an automatic current limiting circuit.
5. Performance:
 - a. Output voltage nominally 25-V dc within 5 percent.
 - b. Output current up to 100 mA.
 - c. Input voltage nominally 120-V ac, 60 Hz.
 - d. Load regulation within 0.5 percent from zero- to 100-mA load.
 - e. Line regulation within 0.5 percent at a 100-mA load for a 10 percent line change.
 - f. Stability within 0.1 percent of rated volts for 24 hours after a 20-minute warmup.

2.21 UNINTERRUPTABLE POWER SUPPLY (UPS) UNITS FOR WORKSTATIONS

A. 250 through 1000 VA:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. APC.
 - b. Cyberpower.
2. UPS units shall provide continuous, regulated output power without using their batteries during brown-out, surge, and spike conditions.
3. Load served shall not exceed 75 percent of UPS rated capacity, including power factor of connected loads.
 - a. Larger-capacity units shall be provided for systems with larger connected loads.
 - b. UPS shall provide 30 minutes of battery power.
4. Performance:
 - a. Input Voltage: Single phase, 120- or 230-V ac, compatible with field power source.
 - b. Load Power Factor Range (Crest Factor): 0.65 to 1.0.
 - c. Output Voltage: 101- to 132-V ac, while input voltage varies between 89 and 152-V ac.
 - d. On Battery Output Voltage: Sine wave.
 - e. Inverter overload capacity shall be minimum 150 percent for 30 seconds.

- f. Recharge time shall be a maximum of six hours to 90 percent capacity after full discharge to cutoff.
 - g. Transfer Time: 6 ms.
 - h. Surge Voltage Withstand Capacity: IEEE C62.41, Categories A and B; 6 kV/200 and 500 A; 100-kHz ringwave.
- 5. UPS shall be automatic during fault or overload conditions.
- 6. Unit with integral line-interactive, power condition topology to eliminate all power contaminants.
- 7. Include front panel with power switch and visual indication of power, battery, fault and temperature.
- 8. Unit shall include an audible alarm of faults and front panel silence feature.
- 9. Unit with four NEMA WD 1, NEMA WD 6 Configuration 5-15R receptacles.
- 10. UPS shall include dry contacts (digital output points) for low battery condition and battery-on (primary utility power failure) and connect the points to the DDC system.
- 11. Batteries shall be sealed lead-acid type and be maintenance free. Battery replacement shall be front accessible by user without dropping load.
- 12. Include tower models installed in ventilated cabinets to the particular installation location.

2.22 PROCESS TUBING

- A. Products in this article are intended for signals to instruments connected to liquid and steam systems.
- B. Copper Tubing:
 - 1. Seamless phosphor deoxidized copper, soft annealed or drawn tempered with chemical and physical properties according to ASTM B75.
 - 2. Performance, dimensions, weight and tolerance according to ASTM B280.
 - 3. Diameter, as required by application, of not less than nominal 0.25 inch.
 - 4. Wall thickness, as required by application, but not less than 0.030 inch.
 - 5. Copper Tubing Connectors and Fittings (for Process Tubing) - Brass, Compression Type:
 - a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) BrassCraft Manufacturing Co.; a Masco company.
 - 2) DK-LOK USA.
 - 3) Parker Hannifin Corporation.
 - 6. Copper Tubing Connectors and Fittings (for Process Tubing) - Brass, Solder-Joint Type:
 - a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Elkhart Products Corporation; a part of Aalberts Integrated Piping Systems.
 - 2) NIBCO INC.
- C. Stainless Steel Tubing (for Process Tubing):
 - 1. Seamless Type 316 stainless steel, Grade TP, cold drawn, annealed and pickled, free from scale.
 - 2. Chemical and physical properties according to ASTM A269.
 - 3. Diameter, as required by application, of not less than nominal 0.25 inch.
 - 4. Wall thickness, as required by application, but not less than 0.035 inch.
 - 5. Furnish stainless steel tubing in 20-foot straight random lengths.

D. Stainless Steel Tubing Connectors and Fittings (for Process Tubing):

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. DK-LOK USA.
 - b. Parker Hannifin Corporation.
2. Connectors and fittings shall be stainless steel, with stainless steel collets, flareless type.
3. Connect instruments to tubing with connectors having compression connector on one end and IPS or NPT thread on other end.

2.23 CONTROL WIRE AND CABLE

A. Wire: Single conductor control wiring above 24 V.

1. Wire size shall be at least No. 16 AWG.
2. Conductor shall be 7/24 soft annealed copper strand with 2- to 2.5-inch lay.
3. Conductor insulation shall be 600 V, Type THWN or Type THHN, and 90 deg C according to UL 83.
4. Conductor colors shall be black (hot), white (neutral), and green (ground).
5. Furnish wire on spools.

B. Single Twisted Shielded Instrumentation Cable above 24 V:

1. Wire size shall be a minimum No. 18 AWG.
2. Conductors shall be a twisted, 7/24 soft annealed copper strand with a 2- to 2.5-inch lay.
3. Conductor insulation shall have a Type THHN/THWN or Type TFN rating.
4. Shielding shall be 100 percent type, 0.35/0.5-mil aluminum/Mylar tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
5. Outer jacket insulation shall have a 600-V, 90-deg C rating and shall be Type TC cable.
6. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red and white.
7. Furnish wire on spools.

C. Single Twisted Shielded Instrumentation Cable 24 V and Less:

1. Wire size shall be a minimum No. 18 AWG.
2. Conductors shall be a twisted, 7/24 soft annealed copper stranding with a 2- to 2.5-inch lay.
3. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame-retardant PVC.
4. Shielding shall be 100 percent type, 1.35-mil aluminum/polymer tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
5. Outer jacket insulation shall have a 300-V, 105-deg C rating and shall be Type PLTC cable.
6. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red and white.
7. Furnish wire on spools.

D. LAN and Communication Cable: Comply with DDC system manufacturer requirements for network being installed.

1. Cable shall be balanced twisted pair.

2. Comply with the following requirements and for balanced twisted pair cable described in Section 260523 "Control-Voltage Electrical Power Cables." Section 271513 "Communications Copper Horizontal Cabling."
 - a. Cable shall be plenum rated.
 - b. Cable shall have a unique color that is different from other cables used on Project.

2.24 RACEWAYS

- A. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for electrical power raceways and boxes.
- B. Comply with requirements in Section 270528 "Pathways for Communications Systems" for raceways for balanced twisted pair cables and optical fiber cables.

2.25 OPTICAL FIBER CABLE AND CONNECTORS

- A. Comply with requirements in Section 271323 "Communications Optical Fiber Backbone Cabling" for optical fiber backbone cabling and connectors.
- B. Comply with requirements in Section 271523 "Communications Optical Fiber Horizontal Cabling" for optical fiber horizontal cabling and connectors.

2.26 ACCESSORIES

- A. Damper Blade Limit Switches:
 1. Sense positive open and/or closed position of the damper blades.
 2. NEMA 250, Type 13, oil-tight construction.
 3. Arrange for the mounting application.
 4. Additional waterproof enclosure when required by its environment.
 5. Arrange to prevent "over-center" operation.
- B. Instrument Enclosures:
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Hammond Mfg. Co. Inc.
 - b. Hoffman; brand of nVent Electrical plc.
 - c. Saginaw Control and Engineering.
 2. Include instrument enclosure for secondary protection to comply with requirements indicated in "Performance Requirements" Article.
 3. NRTL listed and labeled to UL 50.
 4. Sized to include at least 25 percent spare area on subpanel.
 5. Instrument(s) mounted within enclosure on internal subpanel(s).
 6. Enclosure face with engraved, laminated phenolic nameplate for each instrument within enclosure.
 7. Enclosures housing pneumatic instruments shall include main pressure gauge and a branch pressure gauge for each pneumatic device, installed inside.
 8. Enclosures housing multiple instruments shall route tubing and wiring within enclosure in a raceway having a continuous removable cover.
 9. Enclosures larger than 12 inches shall have a hinged full-size face cover.
 10. Equip enclosure with lock and common key.

C. Manual Valves:

1. Ball Type:

- a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Apollo Valves; a part of Aalberts Integrated Piping Systems.
 - 2) Milwaukee Valve Company.
 - 3) NIBCO INC.
- b. Body: Bronze ASTM B62 or ASTM B61.
- c. Ball: Type 316 stainless steel.
- d. Stem: Type 316 stainless steel.
- e. Seats: Reinforced PTFE.
- f. Packing Ring: Reinforced PTFE.
- g. Lever: Stainless steel with a vinyl grip.
- h. 600 WOG.
- i. Threaded end connections.

2.27 IDENTIFICATION

A. Instrument Air Pipe and Tubing:

- 1. Engraved tag shall bear the following information:
 - a. Service (Example): "Instrument Air."
 - b. Pressure Range (Example): 0 to 30 psig.
- 2. Letter size shall be a minimum of 0.25 inch high.
- 3. Tag shall consist of white lettering on blue background.
- 4. Tag shall be engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers are color-coded blue with contrasting white center exposed by engraving through outer layer.
- 5. Include tag with a brass grommet, chain and S-hook.

B. Control Equipment, Instruments, and Control Devices:

- 1. Laminated acrylic or melamine plastic sign bearing unique identification.
 - a. Include instruments with unique identification identified by equipment being controlled or monitored, followed by point identification.
- 2. Letter size shall be as follows:
 - a. Operator Workstations: Minimum of 0.5 inch high.
 - b. Servers: Minimum of 0.5 inch high.
 - c. Printers: Minimum of 0.5 inch high.
 - d. DDC Controllers: Minimum of 0.5 inch high.
 - e. Gateways: Minimum of 0.5 inch high.
 - f. Repeaters: Minimum of 0.5 inch high.
 - g. Enclosures: Minimum of 0.5 inch high.
 - h. Electrical Power Devices: Minimum of 0.25 inch high.
 - i. UPS units: Minimum of 0.5 inch high.
 - j. Accessories: Minimum of 0.25 inch high.
 - k. Instruments: Minimum of 0.25 inch high.

1. Control Damper and Valve Actuators: Minimum of 0.25 inch high.
 3. Legend shall consist of white lettering on black background.
 4. Laminated acrylic or melamine plastic sign shall be engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers are color-coded black with contrasting white center exposed by engraving through outer layer and shall be fastened with drive pins.
 5. Instruments, control devices, and actuators with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require additional identification.
 - C. Valve Tags:
 1. Brass tags and brass chains attached to valve.
 2. Tags shall be at least 1.5 inches in diameter.
 3. Include tag with unique valve identification indicating control influence such as flow, level, pressure, or temperature; followed by location of valve, and followed by three-digit sequential number. For example: TV-1.001.
 4. Valves with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require an additional tag.
 - D. Raceway and Boxes:
 1. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
 2. Paint cover plates on junction boxes and conduit same color as the tape banding for conduits. After painting, label cover plate "HVAC Controls," using an engraved phenolic tag.
 3. For raceways housing pneumatic tubing, add a phenolic tag labeled "HVAC Instrument Air Tubing."
 4. For raceways housing air signal tubing, add a phenolic tag labeled "HVAC Air Signal Tubing."
 - E. Equipment Warning Labels:
 1. Self-adhesive label with pressure-sensitive adhesive back and peel-off protective jacket.
 2. Lettering size shall be at least 14-point type with white lettering on red background.
 3. Warning label shall read "CAUTION-Equipment operated under remote automatic control and may start or stop at any time without warning. Switch electric power disconnecting means to OFF position before servicing."
 4. Lettering shall be enclosed in a white line border. Edge of label shall extend at least 0.25 inch beyond white border.

2.28 SOURCE QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to evaluate the following according to industry standards for each product, and to verify DDC system reliability specified in performance requirements:
 1. DDC controllers.
 2. Gateways.
 3. Routers.
 4. Operator workstations.
- B. Product(s) and material(s) will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
 - 1. Verify compatibility with and suitability of substrates.
- B. Examine roughing-in for products to verify actual locations of connections before installation.
 - 1. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
 - 2. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- C. Examine walls, floors, roofs, and ceilings for suitable conditions where product will be installed.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 DDC SYSTEM INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT

- A. Communication Interface to Equipment with Integral Controls:
 - 1. DDC system shall have communication interface with equipment having integral controls and having a communication interface for remote monitoring or control.
 - 2. Equipment to Be Connected:
 - a. Air-terminal units specified in Section 233600 "Air Terminal Units."
 - b. Boilers specified in Section 235216 "Condensing Boilers."
 - c. Chillers specified in Section 236423.16 "Water-Cooled, Scroll Water Chillers."
 - d. Chillers specified in Section 236426.13 "Air-Cooled, Rotary-Screw Water Chillers."
 - e. Cooling towers specified in Section 236513.13 "Open-Circuit, Forced-Draft Cooling Towers."
 - f. Cooling towers specified in Section 236513.16 "Closed-Circuit, Forced-Draft Cooling Towers."
 - g. Cooling towers specified in Section 236514.13 "Open-Circuit, Induced-Draft, Counterflow Cooling Towers."
 - h. Cooling towers specified in Section 236514.14 "Open-Circuit, Induced-Draft, Crossflow Cooling Towers."
 - i. Cooling towers specified in Section 236514.16 "Closed-Circuit, Induced-Draft, Counterflow Cooling Towers."
 - j. Cooling towers specified in Section 236514.17 "Closed-Circuit, Induced-Draft, Combined-Flow Cooling Towers."
 - k. Heat wheels and heat exchangers specified in Section 237223 "Air-to-Air Energy Recovery Equipment."
 - l. Air-handling units specified in Section 237313 "Modular Indoor Central-Station Air-Handling Units."
 - m. Roof-top units specified in Section 237413 "Packaged, Outdoor, Central-Station Air-Handling Units."
 - n. Dedicated outdoor-air units specified in Section 237433 "Dedicated Outdoor-Air Units."

- o. Packaged terminal air-conditioners specified in Section 238113.11 "Packaged Terminal Air-Conditioners, Through-Wall Units."
- p. Packaged terminal air-conditioners specified in Section 238113.12 "Packaged Terminal Air-Conditioners, Freestanding Units."
- q. Packaged terminal air-conditioners specified in Section 238113.13 "Packaged Terminal Air-Conditioners, Outdoor, Wall-Mounted Units."
- r. Fan-coil units specified in Section 238219 "Fan Coil Units."
- s. Unit ventilators specified in Section 238223 "Unit Ventilators."
- t. Wetted-element humidifiers specified in Section 238413.16 "Wetted-Element Humidifiers."
- u. Atomizing humidifiers specified in Section 238413.19 "Atomizing Humidifiers."
- v. Direct-steam-injection humidifiers specified in Section 238413.23 "Direct-Steam-Injection Humidifiers."
- w. Self-contained steam humidifiers specified in Section 238413.29 "Self-Contained Steam Humidifiers."
- x. Heat exchanger humidifiers specified in Section 238413.36 "Heat Exchanger Humidifiers."
- y. Switchboards specified in Section 262300 "Low-Voltage Switchgear."
- z. Motor-control centers specified in Section 262419 "Motor-Control Centers."
- aa. Variable-frequency controllers specified in Section 262923 "Variable-Frequency Motor Controllers."
- bb. Diesel emergency engine generators specified in Section 263213.13 "Diesel-Engine-Driven Generator Sets."
- cc. Gaseous emergency engine generators specified in Section 263213.16 "Gas-Engine-Driven Generator Sets."
- dd. Bi-fuel emergency engine generators specified in Section 263213.19 "Bi-Fuel-Engine-Driven Generator Sets."

B. Communication Interface to Other Building Systems:

- 1. DDC system shall have a communication interface with systems having a communication interface.
- 2. Systems to Be Connected:
 - a. Automated water treatment systems specified in Section 232500 "HVAC Water Treatment."
 - b. Power monitoring specified in Section 260913 "Electrical Power Monitoring and Control."
 - c. Lighting controls specified in Section 260926 "Lighting Control Panelboards."
 - d. Lighting controls specified in Section 260943.23 "Relay-Based Lighting Controls."
 - e. Fire-alarm system specified in Section 284621.11 "Addressable Fire-Alarm Systems."
 - f. Fire-alarm system specified in Section 284621.13 "Conventional Fire-Alarm Systems."

3.3 DDC SYSTEM INTERFACE WITH EXISTING SYSTEMS

A. Integration with Existing Enterprise System:

- 1. DDC system shall interface with an existing enterprise system to adhere to Owner standards already in-place and to achieve integration.
- 2. Owner's control system integrator will provide the following services:
 - a. Enterprise system expansion and development of graphics, logs, reports, trends and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
 - b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.
 - c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.

3. Engage Owner's control system integrator to provide the following services:
 - a. Enterprise system expansion and development of graphics, logs, reports, trends and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
 - b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.
 - c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.
4. Attend meetings with control system integrator to integrate DDC system.

3.4 CONTROL DEVICES FOR INSTALLATION BY INSTALLERS

- A. Deliver selected control devices, specified in indicated HVAC instrumentation and control device Sections, to identified equipment and systems manufacturers for factory installation and to identified installers for field installation.
- B. Deliver the following to duct fabricator and Installer for installation in ductwork. Include installation instructions to Installer and supervise installation for compliance with requirements.
 1. DDC control dampers, which are specified in Section 230923.12 "Control Dampers."
 2. Airflow sensors and switches, which are specified in Section 230923.14 "Flow Instruments."
 3. Pressure sensors, which are specified in Section 230923.23 "Pressure Instruments."
- C. Deliver the following to plumbing and HVAC piping installers for installation in piping. Include installation instructions to Installer and supervise installation for compliance with requirements.
 1. DDC control valves, which are specified in Section 230923.11 "Control Valves."
 2. Pipe-mounted flow meters, which are specified in Section 230923.14 "Flow Instruments."
 3. Pipe-mounted sensors, switches, and transmitters. Flow meters are specified in Section 230923.14 "Flow Instruments."
 4. Tank-mounted sensors, switches, and transmitters. Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments."
 5. Liquid and steam temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
 6. Pipe- and tank-mounted thermowells. Liquid and steam thermowells are specified in Section 230923.27 "Temperature Instruments."

3.5 CONTROL DEVICES FOR EQUIPMENT MANUFACTURER FACTORY INSTALLATION

- A. Deliver the following to air-handling unit manufacturer for factory installation. Include installation instructions to air-handling unit manufacturer.
 1. Programmable application or application-specific controller.
 2. Unit-mounted DDC control dampers and actuators, which are specified in Section 230923.12 "Control Dampers."
 3. Unit-mounted airflow sensors, switches, and transmitters, which are specified in Section 230923.14 "Flow Instruments."
 4. Unit-mounted gas sensors, and transmitters, which are specified in Section 230923.16 "Gas Instruments."
 5. Unit-mounted leak-detection switches, which are specified in Section 230923.18 "Leak Detection Instruments."

6. Unit-mounted pressure sensors, switches, and transmitters, which are specified in Section 230923.23 "Pressure Instruments."
 7. Unit-mounted speed sensors, switches, and transmitters, which are specified in Section 230923.24 "Speed Instruments."
 8. Unit-mounted temperature sensors, switches, and transmitters. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
 9. Relays.
- B. Deliver the following to terminal unit manufacturer for factory installation. Include installation instructions to terminal unit manufacturer.
1. Programmable application or application-specific controller.
 2. Electric damper actuator. Damper actuators are specified in Section 230923.12 "Control Dampers."
 3. Unit-mounted flow and pressure sensors, transmitters, and transducers. Flow sensors, transmitters, and transducers are specified in Section 230923.14 "Flow Instruments." Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments."
 4. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
 5. Relays.
- C. Deliver the following to fan-coil unit manufacturer for factory installation. Include installation instructions to fan-coil unit manufacturer.
1. Programmable application or application-specific controller.
 2. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
 3. Flow and pressure switches. Air and liquid flow sensors, transmitters, and transducers are specified in Section 230923.14 "Flow Instruments." Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments."
 4. Leak-detection switches, which are specified in Section 230923.18 "Leak Detection Instruments."
 5. Relays.

3.6 GENERAL INSTALLATION REQUIREMENTS

- A. Install products to satisfy more stringent of all requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Support products, tubing, piping wiring and raceways. Brace products to prevent lateral movement and sway or a break in attachment when subjected to a force.
- D. If codes and referenced standards are more stringent than requirements indicated, comply with requirements in codes and referenced standards.
- E. Fabricate openings and install sleeves in ceilings, floors, roof, and walls required by installation of products. Before proceeding with drilling, punching, and cutting, check for concealed work to avoid damage. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- F. Firestop Penetrations Made in Fire-Rated Assemblies: Comply with requirements in Section 078413 "Penetration Firestopping."
- G. Seal penetrations made in acoustically rated assemblies. Comply with requirements in Section 079200 "Joint Sealants."

H. Welding Requirements:

1. Restrict welding and burning to supports and bracing.
2. No equipment shall be cut or welded without approval. Welding or cutting will not be approved if there is risk of damage to adjacent Work.
3. Welding, where approved, shall be by inert-gas electric arc process and shall be performed by qualified welders according to applicable welding codes.
4. If requested on-site, show satisfactory evidence of welder certificates indicating ability to perform welding work intended.

I. Fastening Hardware:

1. Stillson wrenches, pliers, and other tools that damage surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening fasteners.
2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
3. Lubricate threads of bolts, nuts and screws with graphite and oil before assembly.

J. If product locations are not indicated, install products in locations that are accessible and that will permit service and maintenance from floor, equipment platforms, or catwalks without removal of permanently installed furniture and equipment.

K. Corrosive Environments:

1. Avoid or limit use of materials in corrosive airstreams and environments, including, but not limited to, the following:
 - a. Laboratory exhaust-air streams.
 - b. Process exhaust-air streams.
2. When conduit is in contact with a corrosive airstream and environment, use Type 316 stainless steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment. Comply with requirements for installation of raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."
3. Where instruments are located in a corrosive airstream and are not corrosive resistant from manufacturer, field install products in NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.7 WORKSTATION INSTALLATION

A. Desktop Workstations Installation:

1. Install workstation(s) at location(s) directed by Owner.
2. Install multiple-receptacle power strip with cord for use in connecting multiple workstation components to a single duplex electrical power receptacle.
3. Install software on workstation(s) and verify software functions properly.
4. Develop Project-specific graphics, trends, reports, logs and historical database.
5. Power each workstation through a dedicated UPS unit. Locate UPS adjacent to workstation.

B. Portable Workstations Installation:

1. Turn over portable workstations to Owner at Substantial Completion.
2. Install software on workstation(s) and verify software functions properly.

C. Color Graphics Application:

1. Use system schematics indicated as starting point to create graphics.
2. Develop Project-specific library of symbols for representing system equipment and products.
3. Incorporate digital images of Project-completed installation into graphics where beneficial to enhance effect.
4. Submit sketch of graphic layout with description of all text for each graphic for Owner's review before creating graphic using graphics software.
5. Seek Owner input in graphics development once using graphics software.
6. Final editing shall be done on-site with Owner's review and feedback.
7. Refine graphics as necessary for Owner acceptance.
8. On receiving Owner acceptance, print a hard copy for inclusion in operation and maintenance manual. Prepare a scanned copy PDF file of each graphic and include with softcopy of DDC system operation and maintenance manual.

D. Wall-Mounted Portable Operator's Workstation Cabinet Installation:

1. Install wall-mounted portable operator's workstation cabinet(s) at location(s) indicated on Drawings.
2. Install wall-mounted portable operator's workstation cabinet(s) at following location(s) and at locations directed by Owner:
 - a. Each mechanical room.
 - b. Chiller room.
 - c. Boiler room.
3. Connect each cabinet to 120-V, single-phase, 60Hz field power source, and install single gang electrical box with NEMA WD 6, Type 20R duplex receptacle and metal cover plate in cabinet. Comply with requirements in Section 262726 "Wiring Devices."
4. Connect each cabinet to Ethernet network and install an Ethernet network port for connection to portable operator workstation Ethernet cable. Comply with requirements in Section 271513 "Communications Copper Horizontal Cabling."

3.8 SERVER INSTALLATION

- A. Install one server at location(s) directed by Owner.
- B. Install number of servers required to suit requirements indicated. Review Project requirements and indicate layout of proposed location in Shop Drawings.
- C. Install software indicated on server(s) and verify that software functions properly.
- D. Develop Project-specific graphics, trends, reports, logs, and historical database.
- E. Power servers through dedicated UPS unit. Locate UPS adjacent to server.

3.9 CONTROLLER INSTALLATION

- A. Install controllers in enclosures to comply with indicated requirements.
- B. Connect controllers to field power supply.
- C. Install controller with latest version of applicable software and configure to execute requirements indicated.

- D. Test and adjust controllers to verify operation of connected I/O to achieve performance indicated requirements while executing sequences of operation.
- E. Installation of Network Controllers:
 - 1. Quantity and location of network controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
 - 2. Install controllers in a protected location that is easily accessible by operators.
 - 3. Top of controller shall be within 72 inches of finished floor.
- F. Installation of Programmable Application Controllers:
 - 1. Quantity and location of programmable application controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
 - 2. Install controllers in a protected location that is easily accessible by operators.
 - 3. Top of controller shall be within 72 inches of finished floor.
- G. Application-Specific Controllers:
 - 1. Quantity and location of application-specific controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
 - 2. For controllers not mounted directly on equipment being controlled, install controllers in a protected location that is easily accessible by operators.

3.10 ENCLOSURES INSTALLATION

- A. Install the following items in enclosures, to comply with indicated requirements:
 - 1. Gateways.
 - 2. Routers.
 - 3. Controllers.
 - 4. Electrical power devices.
 - 5. UPS units.
 - 6. Relays.
 - 7. Accessories.
 - 8. Instruments.
 - 9. Actuators
- B. Attach wall-mounted enclosures to wall using the following types of steel struts:
 - 1. For NEMA 250, Type 1 Enclosures: Use painted steel strut and hardware.
 - 2. For NEMA 250, Type 4X Enclosures and Enclosures Located Outdoors: Use stainless steel strut and hardware.
 - 3. Install plastic caps on exposed cut edges of strut.
- C. Align top of adjacent enclosures.
- D. Install floor-mounted enclosures located in mechanical equipment rooms on concrete housekeeping pads. Attach enclosure legs using stainlesssteel anchors.
- E. Install continuous and fully accessible wireways to connect conduit, wire, and cable to multiple adjacent enclosures. Wireway used for application shall have protection equal to NEMA 250 rating of connected enclosures.

3.11 ELECTRIC POWER CONNECTIONS

- A. Connect electrical power to DDC system products requiring electrical power connections.
- B. Design of electrical power to products not indicated with electric power is delegated to DDC system provider and installing trade. Work shall comply with NFPA 70 and other requirements indicated.
- C. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers" for electrical power circuit breakers.
- D. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for electrical power conductors and cables.
- E. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for electrical power raceways and boxes.

3.12 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements in Section 260553 "Identification for Electrical Systems" for identification products and installation.
- B. Install laminated acrylic or melamine plastic signs with unique identification on face for each of the following:
 - 1. Operator workstation.
 - 2. Server.
 - 3. Printer.
 - 4. Router.
 - 5. Protocol analyzer.
 - 6. DDC controller.
 - 7. Enclosure.
 - 8. Electrical power device.
 - 9. UPS unit.
 - 10. Accessory.
- C. Install unique instrument identification on face of each instrument connected to a DDC controller.
- D. Install unique identification on face of each control damper and valve actuator connected to a DDC controller.
- E. Where product is installed above accessible tile ceiling, also install matching identification on face of ceiling grid located directly below.
- F. Where product is installed above an inaccessible ceiling, also install identification on face of access door directly below.
- G. Warning Labels and Signs:
 - 1. Shall be permanently attached to equipment that can be automatically started by DDC control system.
 - 2. Shall be located in highly visible location near power service entry points.

3.13 NETWORK INSTALLATION

- A. Install optical fiber cable when connecting between the following network devices and when located in different buildings on campus, or when distance between devices exceeds 330 Feet :
 - 1. Operator workstations.
 - 2. Operator workstations and network controllers.
 - 3. Network controllers.
- B. Install balanced twisted pair or optical fiber cable when connecting between the following network devices located in same building:
 - 1. Operator workstations.
 - 2. Operator workstations and network controllers.
 - 3. Network controllers.
- C. Install balanced twisted pair or copper cable (as required by equipment) when connecting between the following:
 - 1. Gateways.
 - 2. Gateways and network controllers or programmable application controllers.
 - 3. Routers.
 - 4. Routers and network controllers or programmable application controllers.
 - 5. Network controllers and programmable application controllers.
 - 6. Programmable application controllers.
 - 7. Programmable application controllers and application-specific controllers.
 - 8. Application-specific controllers.
- D. Install cable in continuous raceway.
 - 1. Where indicated on Drawings, cable trays may be used for copper cable in lieu of conduit.

3.14 NETWORK NAMING AND NUMBERING

- A. Coordinate with Owner and provide unique naming and addressing for networks and devices.
- B. ASHRAE 135 Networks:
 - 1. MAC Address:
 - a. Every network device shall have an assigned and documented MAC address unique to its network.
 - b. Ethernet Networks: Document MAC address assigned at its creation.
 - c. ARCNET or MS/TP networks: Assign from 00 to 64.
 - 2. Network Numbering:
 - a. Assign unique numbers to each new network.
 - b. Provide ability for changing network number through device switches or operator interface.
 - c. DDC system, with all possible connected LANs, can contain up to 65,534 unique networks.
 - 3. Device Object Identifier Property Number:
 - a. Assign unique device object identifier property numbers or device instances for each device network.

- b. Provide for future modification of device instance number by device switches or operator interface.
 - c. LAN shall support up to 4,194,302 unique devices.
- 4. Device Object Name Property Text:
 - a. Device object name property field shall support 32 minimum printable characters.
 - b. Assign unique device "Object Name" property names with plain-English descriptive names for each device.
 - 1) Example 1: Device object name for device controlling boiler plant at Building 1000 would be "HW System B1000."
 - 2) Example 2: Device object name for a VAV terminal unit controller could be "VAV unit 102".
- 5. Object Name Property Text for Other Than Device Objects:
 - a. Object name property field shall support 32 minimum printable characters.
 - b. Assign object name properties with plain-English names descriptive of application.
 - 1) Example 1: "Zone 1 Temperature."
 - 2) Example 2 "Fan Start and Stop."
- 6. Object Identifier Property Number for Other Than Device Objects:
 - a. Assign object identifier property numbers according to Drawings or tables indicated.
 - b. If not indicated, object identifier property numbers may be assigned at Installer's discretion but must be approved by Owner in advance, be documented and be unique for like object types within device.

3.15 CONTROL WIRE, CABLE AND RACEWAYS INSTALLATION

A. Comply with NECA 1.

B. Wire and Cable Installation:

- 1. Comply with installation requirements in Section 260523 "Control-Voltage Electrical Power Cables."
- 2. Comply with installation requirements in Section 271313 "Communications Copper Backbone Cabling."
- 3. Comply with installation requirements in Section 271513 "Communications Copper Horizontal Cabling."
- 4. Install cables with protective sheathing that is waterproof and capable of withstanding continuous temperatures of 90 deg C with no measurable effect on physical and electrical properties of cable.
 - a. Provide shielding to prevent interference and distortion from adjacent cables and equipment.
- 5. Terminate wiring in a junction box.
 - a. Clamp cable over jacket in junction box.
 - b. Individual conductors in the stripped section of the cable shall be slack between the clamping point and terminal block.
- 6. Terminate field wiring and cable not directly connected to instruments and control devices having integral wiring terminals using terminal blocks.

7. Install signal transmission components according to IEEE C2, REA Form 511a, NFPA 70, and as indicated.
8. Use shielded cable to transmitters.
9. Use shielded cable to temperature sensors.
10. Perform continuity and meager testing on wire and cable after installation.

C. Conduit Installation:

1. Comply with Section 260533 "Raceways and Boxes for Electrical Systems" for control-voltage conductors.
2. Comply with Section 270528 "Pathways for Communications Systems" for balanced twisted pair cabling and optical fiber installation.

3.16 OPTICAL FIBER CABLE SYSTEM INSTALLATION

- A. Comply with installation requirements in Section 271323 "Communications Optical Fiber Backbone Cabling."
- B. Comply with installation requirements in Section 271523 "Communications Optical Fiber Horizontal Cabling."

3.17 FIELD QUALITY CONTROL

- A. Testing Agency: a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.
- C. Testing:
 1. Perform preinstallation, in-progress, and final tests, supplemented by additional tests, as necessary.
 2. Preinstallation Cable Verification: Verify integrity and serviceability for new cable lengths before installation. This assurance may be provided by using vendor verification documents, testing, or other methods. As a minimum, furnish evidence of verification for cable attenuation and bandwidth parameters.
 3. In-Progress Testing: Perform standard tests for correct pair identification and termination during installation to ensure proper installation and cable placement. Perform tests in addition to those specified if there is any reason to question condition of material furnished and installed. Testing accomplished is to be documented by agency conducting tests. Submit test results for Project record.
 4. Final Testing: Perform final test of installed system to demonstrate acceptability as installed. Testing shall be performed according to a test plan supplied by DDC system manufacturer. Defective Work or material shall be corrected and retested. As a minimum, final testing for cable system, including spare cable, shall verify conformance of attenuation, length, and bandwidth parameters with performance indicated.
 5. Test Equipment: Use an optical fiber time domain reflectometer for testing of length and optical connectivity.
 6. Test Results: Record test results and submit copy of test results for Project record.

3.18 DDC SYSTEM I/O CHECKOUT PROCEDURES

- A. Check installed products before continuity tests, leak tests and calibration.

- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
- D. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material and support.
- E. For pneumatic products, verify that air supply for each product is properly installed.
- F. Control Damper Checkout:
 - 1. Verify that control dampers are installed correctly for flow direction.
 - 2. Verify that proper blade alignment, either parallel or opposed, has been provided.
 - 3. Verify that damper frame attachment is properly secured and sealed.
 - 4. Verify that damper actuator and linkage attachment is secure.
 - 5. Verify that actuator wiring is complete, enclosed and connected to correct power source.
 - 6. Verify that damper blade travel is unobstructed.
- G. Control Valve Checkout:
 - 1. Verify that control valves are installed correctly for flow direction.
 - 2. Verify that valve body attachment is properly secured and sealed.
 - 3. Verify that valve actuator and linkage attachment is secure.
 - 4. Verify that actuator wiring is complete, enclosed and connected to correct power source.
 - 5. Verify that valve ball, disc or plug travel is unobstructed.
 - 6. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.
- H. Instrument Checkout:
 - 1. Verify that instrument is correctly installed for location, orientation, direction and operating clearances.
 - 2. Verify that attachment is properly secured and sealed.
 - 3. Verify that conduit connections are properly secured and sealed.
 - 4. Verify that wiring is properly labeled with unique identification, correct type and size and is securely attached to proper terminals.
 - 5. Inspect instrument tag against approved submittal.
 - 6. For instruments with tubing connections, verify that tubing attachment is secure and isolation valves have been provided.
 - 7. For flow instruments, verify that recommended upstream and downstream distances have been maintained.
 - 8. For temperature instruments:
 - a. Verify sensing element type and proper material.
 - b. Verify length and insertion.

3.19 DDC SYSTEM I/O ADJUSTMENT, CALIBRATION AND TESTING:

- A. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
- B. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.

- C. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
- D. Equipment and procedures used for calibration shall comply with instrument manufacturer's written instructions.
- E. Provide diagnostic and test equipment for calibration and adjustment.
- F. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. An installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
- G. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
- H. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
- I. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.
- J. Analog Signals:
 - 1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
 - 2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
 - 3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.
- K. Digital Signals:
 - 1. Check digital signals using a jumper wire.
 - 2. Check digital signals using an ohmmeter to test for contact making or breaking.
- L. Control Dampers:
 - 1. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
 - 2. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
 - 3. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.
- M. Control Valves:
 - 1. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
 - 2. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
 - 3. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.
- N. Meters: Check sensors at zero, 50, and 100 percent of Project design values.
- O. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.
- P. Switches: Calibrate switches to make or break contact at set points indicated.

Q. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistant source.

3.20 DDC SYSTEM CONTROLLER CHECKOUT

A. Verify power supply.

1. Verify voltage, phase and hertz.
2. Verify that protection from power surges is installed and functioning.
3. Verify that ground fault protection is installed.
4. If applicable, verify if connected to UPS unit.
5. If applicable, verify if connected to a backup power source.
6. If applicable, verify that power conditioning units, transient voltage suppression and high-frequency noise filter units are installed.

B. Verify that wire and cabling is properly secured to terminals and labeled with unique identification.

C. Verify that spare I/O capacity is provided.

3.21 DDC CONTROLLER I/O CONTROL LOOP TESTS

A. Testing:

1. Test every I/O point connected to DDC controller to verify that safety and operating control set points are as indicated and as required to operate controlled system safely and at optimum performance.
2. Test every I/O point throughout its full operating range.
3. Test every control loop to verify operation is stable and accurate.
4. Adjust control loop proportional, integral and derivative settings to achieve optimum performance while complying with performance requirements indicated. Document testing of each control loop's precision and stability via trend logs.
5. Test and adjust every control loop for proper operation according to sequence of operation.
6. Test software and hardware interlocks for proper operation. Correct deficiencies.
7. Operate each analog point at the following:
 - a. Upper quarter of range.
 - b. Lower quarter of range.
 - c. At midpoint of range.
8. Exercise each binary point.
9. For every I/O point in DDC system, read and record each value at operator workstation, at DDC controller and at field instrument simultaneously. Value displayed at operator workstation, at DDC controller and at field instrument shall match.
10. Prepare and submit a report documenting results for each I/O point in DDC system and include in each I/O point a description of corrective measures and adjustments made to achieve desired results.

3.22 DDC SYSTEM VALIDATION TESTS

- A. Perform validation tests before requesting final review of system. Before beginning testing, first submit Pretest Checklist and Test Plan.

- B. After approval of Test Plan, execute all tests and procedures indicated in plan.
- C. After testing is complete, submit completed test checklist.
- D. Pretest Checklist: Submit the following list with items checked off once verified:
 - 1. Detailed explanation for any items that are not completed or verified.
 - 2. Required mechanical installation work is successfully completed and HVAC equipment is working correctly.
 - 3. HVAC equipment motors operate below full-load amperage ratings.
 - 4. Required DDC system components, wiring, and accessories are installed.
 - 5. Installed DDC system architecture matches approved Drawings.
 - 6. Control electric power circuits operate at proper voltage and are free from faults.
 - 7. Required surge protection is installed.
 - 8. DDC system network communications function properly, including uploading and downloading programming changes.
 - 9. Using BACnet protocol analyzer, verify that communications are error free.
 - 10. Each controller's programming is backed up.
 - 11. Equipment, products, tubing, wiring cable, and conduits are properly labeled.
 - 12. All I/O points are programmed into controllers.
 - 13. Testing, adjusting, and balancing work affecting controls is complete.
 - 14. Dampers and actuators zero and span adjustments are set properly.
 - 15. Each control damper and actuator goes to failed position on loss of power.
 - 16. Valves and actuators zero and span adjustments are set properly.
 - 17. Each control valve and actuator goes to failed position on loss of power.
 - 18. Meter, sensor and transmitter readings are accurate and calibrated.
 - 19. Control loops are tuned for smooth and stable operation.
 - 20. View trend data where applicable.
 - 21. Each controller works properly in standalone mode.
 - 22. Safety controls and devices function properly.
 - 23. Interfaces with fire-alarm system function properly.
 - 24. Electrical interlocks function properly.
 - 25. Operator workstations and other interfaces are delivered, all system and database software is installed, and graphic are created.
 - 26. Record Drawings are completed.
- E. Test Plan:
 - 1. Prepare and submit a validation test plan including test procedures for performance validation tests.
 - 2. Test plan shall address all specified functions of DDC system and sequences of operation.
 - 3. Explain detailed actions and expected results to demonstrate compliance with requirements indicated.
 - 4. Explain method for simulating necessary conditions of operation used to demonstrate performance.
 - 5. Include a test checklist to be used to check and initial that each test has been successfully completed.
 - 6. Submit test plan documentation 20 business days before start of tests.
- F. Validation Test:
 - 1. Verify operating performance of each I/O point in DDC system.
 - a. Verify analog I/O points at operating value.
 - b. Make adjustments to out-of-tolerance I/O points.
 - 1) Identify I/O points for future reference.
 - 2) Simulate abnormal conditions to demonstrate proper function of safety devices.

- 3) Replace instruments and controllers that cannot maintain performance indicated after adjustments.
 2. Simulate conditions to demonstrate proper sequence of control.
 3. Readjust settings to design values and observe ability of DDC system to establish desired conditions.
 4. After 24 Hours following Initial Validation Test:
 - a. Re-check I/O points that required corrections during initial test.
 - b. Identify I/O points that still require additional correction and make corrections necessary to achieve desired results.
 5. After 24 Hours of Second Validation Test:
 - a. Re-check I/O points that required corrections during second test.
 - b. Continue validation testing until I/O point is normal on two consecutive tests.
 6. Completely check out, calibrate, and test all connected hardware and software to ensure that DDC system performs according to requirements indicated.
 7. After validation testing is complete, prepare and submit a report indicating all I/O points that required correction and how many validation re-tests it took to pass. Identify adjustments made for each test and indicate instruments that were replaced.
- G. DDC System Response Time Test:
 1. Simulate HLC.
 - a. Heavy load shall be an occurrence of 50 percent of total connected binary COV, one-half of which represent an "alarm" condition, and 50 percent of total connected analog COV, one-half of which represent an "alarm" condition, that are initiated simultaneously on a one-time basis.
 2. Initiate 10 successive occurrences of HLC and measure response time to typical alarms and status changes.
 3. Measure with a timer having at least 0.1-second resolution and 0.01 percent accuracy.
 4. Purpose of test is to demonstrate DDC system, as follows:
 - a. Reaction to COV and alarm conditions during HLC.
 - b. Ability to update DDC system database during HLC.
 5. Passing test is contingent on the following:
 - a. Alarm reporting at printer beginning no more than two seconds after the initiation (time zero) of HLC.
 - b. All alarms, both binary and analog, are reported and printed; none are lost.
 - c. Compliance with response times specified.
 6. Prepare and submit a report documenting HLC tested and results of test including time stamp and print out of all alarms.
- H. DDC System Network Bandwidth Test:
 1. Test network bandwidth usage on all DDC system networks to demonstrate bandwidth usage under DDC system normal operating conditions and under simulated HLC.
 2. To pass, none of DDC system networks shall use more than 70 percent of available bandwidth under normal and HLC operation.

3.23 FINAL REVIEW

- A. Submit written request to Architect and Construction Manager when DDC system is ready for final review. Written request shall state the following:
 - 1. DDC system has been thoroughly inspected for compliance with contract documents and found to be in full compliance.
 - 2. DDC system has been calibrated, adjusted and tested and found to comply with requirements of operational stability, accuracy, speed and other performance requirements indicated.
 - 3. DDC system monitoring and control of HVAC systems results in operation according to sequences of operation indicated.
 - 4. DDC system is complete and ready for final review.
- B. Review by Construction Manager shall be made after receipt of written request. A field report shall be issued to document observations and deficiencies.
- C. Take prompt action to remedy deficiencies indicated in field report and submit a second written request when all deficiencies have been corrected. Repeat process until no deficiencies are reported.
- D. Should more than two reviews be required, DDC system manufacturer and Installer shall compensate entity performing review for total costs, labor and expenses, associated with third and subsequent reviews. Estimated cost of each review shall be submitted and approved by DDC system manufacturer and Installer before making the review.
- E. Prepare and submit closeout submittals and begin procedures indicated in "Extended Operation Test" Article when no deficiencies are reported.
- F. A part of DDC system final review shall include a demonstration to parties participating in final review.
 - 1. Provide staff familiar with DDC system installed to demonstrate operation of DDC system during final review.
 - 2. Provide testing equipment to demonstrate accuracy and other performance requirements of DDC system that is requested by reviewers during final review.
 - 3. Demonstration shall include, but not be limited to, the following:
 - a. Accuracy and calibration of 20 I/O points randomly selected by reviewers. If review finds that some I/O points are not properly calibrated and not satisfying performance requirements indicated, additional I/O points may be selected by reviewers until total I/O points being reviewed that satisfy requirements equals quantity indicated.
 - b. HVAC equipment and system hardwired and software safeties and life-safety functions are operating according to sequence of operation. Up to 20 I/O points shall be randomly selected by reviewers. Additional I/O points may be selected by reviewers to discover problems with operation.
 - c. Correct sequence of operation after electrical power interruption and resumption after electrical power is restored for randomly selected HVAC systems.
 - d. Operation of randomly selected dampers and valves in normal-on, normal-off and failed positions.
 - e. Reporting of alarm conditions for randomly selected alarms, including different classes of alarms, to ensure that alarms are properly received by operators and operator workstations.
 - f. Trends, summaries, logs and reports set-up for Project.
 - g. For up to three HVAC systems randomly selected by reviewers, use graph trends to show that sequence of operation is executed in correct manner and that HVAC systems operate properly through complete sequence of operation including different modes of operations indicated. Show that control loops are stable and operating at set points and respond to changes in set point of 20 percent or more.

- h. Software's ability to communicate with controllers, operator workstations, uploading and downloading of control programs.
- i. Software's ability to edit control programs off-line.
- j. Data entry to show Project-specific customizing capability including parameter changes.
- k. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.
- l. Execution of digital and analog commands in graphic mode.
- m. Spreadsheet and curve plot software and its integration with database.
- n. Online user guide and help functions.
- o. Multitasking by showing different operations occurring simultaneously on four quadrants of split screen.
- p. System speed of response compared to requirements indicated.
- q. For Each Network and Programmable Application Controller:
 - 1) Memory: Programmed data, parameters, trend and alarm history collected during normal operation is not lost during power failure.
 - 2) Operator Interface: Ability to connect directly to each type of digital controller with a portable workstation and mobile device. Show that maintenance personnel interface tools perform as indicated in manufacturer's technical literature.
 - 3) Standalone Ability: Demonstrate that controllers provide stable and reliable standalone operation using default values or other method for values normally read over network.
 - 4) Electric Power: Ability to disconnect any controller safely from its power source.
 - 5) Wiring Labels: Match control drawings.
 - 6) Network Communication: Ability to locate a controller's location on network and communication architecture matches Shop Drawings.
 - 7) Nameplates and Tags: Accurate and permanently attached to control panel doors, instrument, actuators, and devices.
- r. For Each Operator Workstation:
 - 1) I/O points lists agree with naming conventions.
 - 2) Graphics are complete.
 - 3) UPS unit, if applicable, operates.
- s. Communications and Interoperability: Demonstrate proper interoperability of data sharing, alarm and event management, trending, scheduling, and device and network management. Requirements must be met even if only one manufacturer's equipment is installed.
 - 1) Data Presentation: On each operator workstation, demonstrate graphic display capabilities.
 - 2) Reading of Any Property: Demonstrate ability to read and display any used readable object property of any device on network.
 - 3) Set Point and Parameter Modifications: Show ability to modify set points and tuning parameters indicated. Modifications are made with messages and write services initiated by an operator using workstation graphics, or by completing a field in a menu with instructional text.
 - 4) Peer-to-Peer Data Exchange: Network devices are installed and configured to perform without need for operator intervention to implement Project sequence of operation and to share global data.
 - 5) Alarm and Event Management: Alarms and events are installed and prioritized according to Owner. Demonstrate that time delays and other logic are set up to avoid nuisance tripping. Show that operators with sufficient privileges are permitted.

- 6) Schedule Lists: Schedules are configured for start and stop, mode change, occupant overrides, and night setback as defined in sequence of operations.
- 7) Schedule Display and Modification: Ability to display any schedule with start and stop times for calendar year. Show that all calendar entries and schedules are modifiable from any connected operator workstation by an operator with sufficient privilege.
- 8) Archival Storage of Data: Data archiving is handled by operator workstation and server and local trend archiving and display is accomplished.
- 9) Modification of Trend Log Object Parameters: Operator with sufficient privilege can change logged data points, sampling rate, and trend duration.
- 10) Device and Network Management:
 - a) Display of network device status.
 - b) Display of BACnet Object Information.
 - c) Silencing devices transmitting erroneous data.
 - d) Time synchronization.
 - e) Remote device re-initialization.
 - f) Backup and restore network device programming and master database(s).
 - g) Configuration management of routers.

3.24 EXTENDED OPERATION TEST

- A. Extended operation test is intended to simulate normal operation of DDC system by Owner.
- B. Operate DDC system for an operating period of 14 consecutive calendar days following Substantial Completion. Coordinate exact start date of testing with Owner.
- C. Provide an operator familiar with DDC system installed to man an operator workstation while on-site during eight hours of each normal business day occurring during operating period.
- D. During operating period, DDC system shall demonstrate correct operation and accuracy of monitored and controlled points as well as operation capabilities of sequences, logs, trends, reports, specialized control algorithms, diagnostics, and other software indicated.
 1. Correct defects of hardware and software when it occurs.
- E. Definition of Failures and Downtime during Operating Period:
 1. Failed I/O point constituting downtime is an I/O point failing to perform its intended function consistently and a point physically failed due to hardware and software.
 2. Downtime is when any I/O point in DDC system is unable to fulfill its' required function.
 3. Downtime shall be calculated as elapsed time between a detected point failure as confirmed by an operator and time point is restored to service.
 4. Maximum time interval allowed between DDC system detection of failure occurrence and operator confirmation shall be 0.5 hours.
 5. Downtime shall be logged in hours to nearest 0.1 hour.
 6. Power outages shall not count as downtime, but shall suspend test hours unless systems are provided with UPS and served through a backup power source.
 7. Hardware or software failures caused by power outages shall count as downtime.
- F. During operating period, log downtime and operational problems are encountered.
 1. Identify source of problem.
 2. Provide written description of corrective action taken.

3. Record duration of downtime.
 4. Maintain log showing the following:
 - a. Time of occurrence.
 - b. Description of each occurrence and pertinent written comments for reviewer to understand scope and extent of occurrence.
 - c. Downtime for each failed I/O point.
 - d. Running total of downtime and total time of I/O point after each problem has been restored.
 5. Log shall be available to Owner for review at any time.
- G. For DDC system to pass extended operation test, total downtime shall not exceed 2 percent of total point-hours during operating period.
1. Failure to comply with minimum requirements of passing at end of operating period indicated shall require that operating period be extended one consecutive day at a time until DDC system passes requirement.
- H. Evaluation of DDC system passing test shall be based on the following calculation:
1. Downtime shall be counted on a point-hour basis where total number of DDC system point-hours is equal to total number of I/O points in DDC system multiplied by total number of hours during operating period.
 2. One point-hour of downtime is one I/O point down for one hour. Three points down for five hours is a total of 15 point-hours of downtime. Four points down for one-half hour is 2 point-hours of downtime.
 3. Example Calculation: Maximum allowable downtime for 30-day test when DDC system has 1000 total I/O points (combined analog and binary) and has passing score of 1 percent downtime is computed by 30 days x 24 h/day x 1000 points x 1 percent equals 7200 point-hours of maximum allowable downtime.
- I. Prepare test and inspection reports.

3.25 ADJUSTING

- A. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

3.26 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include 12 months' full maintenance by DDC system manufacturer's authorized service representative. Include monthly preventive maintenance, repair or replacement of worn or defective components, cleaning, calibration and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.27 SOFTWARE SERVICE AGREEMENT

- A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for two year(s).

- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within two year(s) from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.
 - 1. Upgrade Notice: At least 30 days to allow Owner to schedule and access system and to upgrade computer equipment if necessary.

3.28 DEMONSTRATION

- A. Engage a factory-authorized service representative with complete knowledge of Project-specific system installed to train Owner's maintenance personnel to adjust, operate, and maintain DDC system.
- B. Extent of Training:
 - 1. Base extent of training on scope and complexity of DDC system indicated and training requirements indicated. Provide extent of training required to satisfy requirements indicated even if more than minimum training requirements are indicated.
 - 2. Inform Owner of anticipated training requirements if more than minimum training requirements are indicated.
 - 3. Minimum Training Requirements:
 - a. Provide not less than 10 days of training total.
 - b. Stagger training over multiple training classes to accommodate Owner's requirements. All training shall occur before end of warranty period.
 - c. Total days of training shall be broken into not more than three separate training classes.
 - d. Each training class shall be not less than two consecutive day(s).
- C. Training Schedule:
 - 1. Schedule training with Owner 20 business days before expected Substantial Completion.
 - 2. Schedule training to provide Owner with at least 15 business days of notice in advance of training.
 - 3. Training shall occur within normal business hours at a mutually agreed on time. Unless otherwise agreed to, training shall occur Monday through Friday, except on U.S. Federal holidays, with two morning sessions and two afternoon sessions. Each morning session and afternoon session shall be split in half with 15 -minute break between sessions. Morning and afternoon sessions shall be separated by 60 -minute lunch period. Training, including breaks and excluding lunch period, shall not exceed eight hours per day.
 - 4. Provide staggered training schedule as requested by Owner.
- D. Training Attendee List and Sign-in Sheet:
 - 1. Request from Owner in advance of training a proposed attendee list with name, phone number and e-mail address.
 - 2. Provide a preprinted sign-in sheet for each training session with proposed attendees listed and no fewer than six blank spaces to add additional attendees.
 - 3. Preprinted sign-in sheet shall include training session number, date and time, instructor name, phone number and e-mail address, and brief description of content to be covered during session. List attendees with columns for name, phone number, e-mail address and a column for attendee signature or initials.
 - 4. Circulate sign-in sheet at beginning of each session and solicit attendees to sign or initial in applicable location.
 - 5. At end of each training day, send Owner an e-mail with an attachment of scanned copy (PDF) of circulated sign-in sheet for each session.

E. Training Attendee Headcount:

1. Plan in advance of training for five attendees.
2. Make allowance for Owner to add up to two attendee(s) at time of training.
3. Headcount may vary depending on training content covered in session. Attendee access may be restricted to some training content for purposes of maintaining system security.

F. Training Attendee Prior Knowledge: For guidance in planning required training and instruction, assume attendees have the following:

1. High school education and degree.
2. Basic user knowledge of computers and office applications.
3. Basic knowledge of HVAC systems.
4. Basic knowledge of DDC systems.
5. Basic knowledge of DDC system and products installed.

G. Attendee Training Manuals:

1. Provide each attendee with a color hard copy of all training materials and visual presentations.
2. Hard-copy materials shall be organized in a three-ring binder with table of contents and individual divider tabs marked for each logical grouping of subject matter. Organize material to provide space for attendees to take handwritten notes within training manuals.
3. In addition to hard-copy materials included in training manual, provide each binder with a sleeve or pocket that includes a DVD or flash drive with PDF copy of all hard-copy materials.

H. Instructor Requirements:

1. One or multiple qualified instructors, as required, to provide training.
2. Instructors shall have not less than five years of providing instructional training on not less than five past projects with similar DDC system scope and complexity to DDC system installed.

I. Organization of Training Sessions:

1. Organize training sessions into logical groupings of technical content and to reflect different levels of operators having access to system. Plan training sessions to accommodate the following three levels of operators:
 - a. Daily operators.
 - b. Advanced operators.
 - c. System managers and administrators.
2. Plan and organize training sessions to group training content to protect DDC system security. Some attendees may be restricted to some training sessions that cover restricted content for purposes of maintaining DDC system security.

J. Training Outline:

1. Submit training outline for Owner review at least 10 business day before scheduling training.
2. Outline shall include a detailed agenda for each training day that is broken down into each of four training sessions that day, training objectives for each training session and synopses for each lesson planned.

K. On-Site Training:

1. Owner will provide conditioned classroom or workspace with ample desks or tables, chairs, power and data connectivity for instructor and each attendee.

2. Instructor shall provide training materials, projector and other audiovisual equipment used in training.
3. Provide as much of training located on-site as deemed feasible and practical by Owner.
4. On-site training shall include regular walk-through tours, as required, to observe each unique product type installed with hands-on review of operation, calibration and service requirements.
5. Operator workstation provided with DDC system shall be used in training. If operator workstation is not indicated, provide a temporary workstation to convey training content.

L. Off-Site Training:

1. Provide conditioned training rooms and workspace with ample tables desks or tables, chairs, power and data connectivity for each attendee.
2. Provide capability to remotely access to Project DDC system for use in training.
3. Provide a workstation for use by each attendee.

M. Training Content for Daily Operators:

1. Basic operation of system.
2. Understanding DDC system architecture and configuration.
3. Understanding each unique product type installed including performance and service requirements for each.
4. Understanding operation of each system and equipment controlled by DDC system including sequences of operation, each unique control algorithm and each unique optimization routine.
5. Operating operator workstations, printers and other peripherals.
6. Logging on and off system.
7. Accessing graphics, reports and alarms.
8. Adjusting and changing set points and time schedules.
9. Recognizing DDC system malfunctions.
10. Understanding content of operation and maintenance manuals including control drawings.
11. Understanding physical location and placement of DDC controllers and I/O hardware.
12. Accessing data from DDC controllers.
13. Operating portable operator workstations.
14. Review of DDC testing results to establish basic understanding of DDC system operating performance and HVAC system limitations as of Substantial Completion.
15. Running each specified report and log.
16. Displaying and demonstrating each data entry to show Project-specific customizing capability. Demonstrating parameter changes.
17. Stepping through graphics penetration tree, displaying all graphics, demonstrating dynamic updating, and direct access to graphics.
18. Executing digital and analog commands in graphic mode.
19. Demonstrating control loop precision and stability via trend logs of I/O for not less than 10 percent of I/O installed.
20. Demonstrating DDC system performance through trend logs and command tracing.
21. Demonstrating scan, update, and alarm responsiveness.
22. Demonstrating spreadsheet and curve plot software, and its integration with database.
23. Demonstrating on-line user guide, and help function and mail facility.
24. Demonstrating multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
25. Demonstrating the following for HVAC systems and equipment controlled by DDC system:
 - a. Operation of HVAC equipment in normal-off, -on and failed conditions while observing individual equipment, dampers and valves for correct position under each condition.
 - b. For HVAC equipment with factory-installed software, show that integration into DDC system is able to communicate with DDC controllers or gateways, as applicable.
 - c. Using graphed trends, show that sequence of operation is executed in correct manner, and HVAC systems operate properly through complete sequence of operation including seasonal

change, occupied and unoccupied modes, warm-up and cool-down cycles and other modes of operation indicated.

- d. Hardware interlocks and safeties function properly and DDC system performs correct sequence of operation after electrical power interruption and resumption after power is restored.
- e. Reporting of alarm conditions for each alarm, and confirm that alarms are received at assigned locations, including operator workstations.
- f. Each control loop responds to set point adjustment and stabilizes within time period indicated.
- g. Sharing of previously graphed trends of all control loops to demonstrate that each control loop is stable and set points are being maintained.

N. Training Content for Advanced Operators:

- 1. Making and changing workstation graphics.
- 2. Creating, deleting and modifying alarms including annunciation and routing.
- 3. Creating, deleting and modifying point trend logs including graphing and printing on an ad-hoc basis and operator-defined time intervals.
- 4. Creating, deleting and modifying reports.
- 5. Creating, deleting and modifying points.
- 6. Creating, deleting and modifying programming including ability to edit control programs off-line.
- 7. Creating, deleting and modifying system graphics and other types of displays.
- 8. Adding DDC controllers and other network communication devices such as gateways and routers.
- 9. Adding operator workstations.
- 10. Performing DDC system checkout and diagnostic procedures.
- 11. Performing DDC controllers operation and maintenance procedures.
- 12. Performing operator workstation operation and maintenance procedures.
- 13. Configuring DDC system hardware including controllers, workstations, communication devices and I/O points.
- 14. Maintaining, calibrating, troubleshooting, diagnosing and repairing hardware.
- 15. Adjusting, calibrating and replacing DDC system components.

O. Training Content for System Managers and Administrators:

- 1. DDC system software maintenance and backups.
- 2. Uploading, downloading and off-line archiving of all DDC system software and databases.
- 3. Interface with Project-specific, third-party operator software.
- 4. Understanding password and security procedures.
- 5. Adding new operators and making modifications to existing operators.
- 6. Operator password assignments and modification.
- 7. Operator authority assignment and modification.
- 8. Workstation data segregation and modification.

P. Video of Training Sessions:

- 1. Provide a digital video and audio recording of each training session. Create a separate recording file for each session.
- 2. Stamp each recording file with training session number, session name and date.
- 3. Provide Owner with two copies of digital files on DVDs or flash drives for later reference and for use in future training.
- 4. Owner retains right to make additional copies for intended training purposes without having to pay royalties.

END OF SECTION 230923

SECTION 230923.11 - CONTROL VALVES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes control valves and actuators for DDC systems.
- B. Related Requirements:
 - 1. Section 230923 "Direct Digital Control (DDC) System for HVAC" control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993.11 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.11.

1.3 DEFINITIONS

- A. Cv: Design valve coefficient.
- B. DDC: Direct-digital control.
- C. NBR: Nitrile butadiene rubber.
- D. PTFE: Polytetrafluoroethylene
- E. RMS: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 3. Product description with complete technical data, performance curves, and product specification sheets.
 - 4. Installation, operation, and maintenance instructions, including factors affecting performance.

B. Shop Drawings:

1. Include plans, elevations, sections, and details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include diagrams for pneumatic signal and main air tubing.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For control valves to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASME Compliance: Fabricate and label products to comply with ASME Boiler and Pressure Vessel Code where required by authorities having jurisdiction.
- C. Ground Fault: Products shall not fail due to ground fault condition when suitably grounded.
- D. Backup Power Source: Systems and equipment served by a backup power source shall have associated control valve actuators served from a backup power source.
- E. Environmental Conditions:
1. Provide electric control valve actuators, with protective enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Electric control valve actuators not available with integral enclosures, complying with requirements indicated, shall be housed in protective secondary enclosures.
 - a. Hazardous Locations: Explosion-proof rating for condition.
- F. Determine control valve sizes and flow coefficients by ISA 75.01.01.
- G. Control valve characteristics and rangeability shall comply with ISA 75.11.01.
- H. Selection Criteria:
1. Control valves shall be suitable for operation at following conditions:
 - a. Chilled Water: 150 PSI 200 Deg F 150% of Pump Head Closeoff.
 - b. Condenser Water: 150 PSI 200 Deg F 150% of Pump Head Closeoff.
 - c. Heat Recovery: 150 PSI 200 Deg F 150% of Pump Head Closeoff.
 - d. Heating Hot Water: 150 PSI 200 Deg F 150% of Pump Head Closeoff.
 - e. Steam: 150 PSI XXXX.
 2. Control valve shutoff classifications shall be FCI 70-2, Class IV or better unless otherwise indicated.
 3. Valve pattern, three-way or straight through, shall be as indicated on Drawings.

4. Modulating straight-through pattern control valves shall have equal percentage flow-throttling characteristics unless otherwise indicated.
5. Modulating three-way pattern water valves shall have linear flow-throttling characteristics. The total flow through the valve shall remain constant regardless of the valve's position.
6. Modulating butterfly valves shall have equal percentage flow-throttling characteristics.
7. Globe-type control valves shall pass the design flow required with not more than 95 percent of stem lift unless otherwise indicated.
8. Rotary-type control valves, such as ball and butterfly valves, shall have Cv falling between 65 and 75 degrees of valve full open position and minimum valve Cv between 15 and 25 percent of open position.
9. Selection shall consider viscosity, flashing, and cavitation corrections.
10. Valves shall have stable operation throughout full range of operation, from design to minimum Cv.
11. In water systems, select modulating control valves at terminal equipment for a design Cv based on a pressure drop of 3 to 5 PSI at design flow unless otherwise indicated.
12. Two-position control valves shall be line size unless otherwise indicated.
13. In water systems, use ball- or globe-style control valves for two-position control for valves NPS 2 and smaller and butterfly style for valves larger than NPS 2.
14. In steam systems, use ball- or globe-style control valves regardless of size.
15. Pneumatic, two-position control valves shall provide a smooth opening and closing characteristic slow enough to avoid water hammer. Valves with pneumatic actuators shall have an adjustable opening time (valve full closed to full open) and an adjustable closing time (valve full open to full closed) ranging from zero to 10 seconds. Opening and closing times shall be independently adjustable.
16. Control valve, pneumatic-control signal shall not exceed 200 feet. For longer distances, provide an electric/electronic control signal to the valve and an electric solenoid valve or electro-pneumatic transducer at the valve to convert the control signal to pneumatic.

2.2 BALL-STYLE CONTROL VALVES

A. Ball Valves with Single Port and Characterized Disk:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Belimo Aircontrols (USA), Inc.
2. Pressure Rating for NPS 1 and Smaller: Nominal 600 WOG.
3. Pressure Rating for NPS 1-1/2 through NPS 2: Nominal 400 WOG.
4. Close-off Pressure: 200 psig.
5. Process Temperature Range: Zero to 212 deg F.
6. Body and Tail Piece: Cast bronze ASTM B 61, ASTM B 62, ASTM B 584, or forged brass with nickel plating.
7. End Connections: Threaded (NPT) ends.
8. Ball: 300 series stainless steel.
9. Stem and Stem Extension:
 - a. Material to match ball.
 - b. Blowout-proof design.
 - c. Sleeve or other approved means to allow valve to be opened and closed without damaging the insulation or the vapor barrier seal.
10. Ball Seats: Reinforced PTFE.
11. Stem Seal: Reinforced PTFE packing ring with a threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if an equivalent cycle endurance can be demonstrated by testing.
12. Flow Characteristic: Equal percentage.

B. Ball Valves with Two Ports and Characterized Disk:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Belimo Aircontrols (USA), Inc.
2. Pressure Rating for NPS 1 and Smaller: Nominal 600 WOG.
3. Pressure Rating for NPS 1-1/2 through NPS 2: Nominal 400 WOG.
4. Close-off Pressure: 200 psig.
5. Process Temperature Range: Zero to 212 deg F.
6. Body and Tail Piece: Cast bronze ASTM B 61, ASTM B 62, ASTM B 584, or forged brass with nickel plating.
7. End Connections: Threaded (NPT) ends.
8. Ball: 300 series stainless steel.
9. Stem and Stem Extension:
 - a. Material to match ball.
 - b. Blowout-proof design.
 - c. Sleeve or other approved means to allow valve to be opened and closed without damaging the insulation or the vapor barrier seal.
10. Ball Seats: Reinforced PTFE.
11. Stem Seal: Reinforced PTFE packing ring with a threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if an equivalent cycle endurance can be demonstrated by testing.
12. Flow Characteristics for A-Port: Equal percentage.
13. Flow Characteristics for B-Port: Modified for constant common port flow.

C. Ball Valves with Single Port and Segmented Ball:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Valve Solutions, Inc.
2. Performance:
 - a. Process Temperature Rating: Minus 20 to plus 450 deg F.
 - b. ASME B16.34, Class 150 or Class 300.
 - c. Leakage: FCI 70-2, Class IV.
 - d. Rangeability: 300 to 1.
 - e. Rotation: Zero to 90 degrees.
 - f. Equal percentage flow characteristic.
3. ASME B16.10 face-to-face dimensions.
4. Valves NPS 2 and Smaller: Threaded (NPT) ends.
5. Valves NPS 2-1/2 through NPS 6: Flanged ends suitable for mating to ASME B16.5 flanges.
6. Body: Carbon steel.
7. Ball and Shaft: Stainless steel.
8. Shaft and Segmented Ball: Pinned and welded.
9. Ball Seat: Graphite.
10. Packing: PTFE V-rings and graphite packing follower.
11. Replaceable seat, ball, and shaft packing.
12. Label each valve with following:
 - a. Manufacturer's name, model number, and serial number.

- b. Body size.
- c. Flow directional arrow.

D. Ball Valves with Segmented Ball, Three-Way Pattern:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Valve Solutions, Inc.
2. Arrangement: Two single-port valves mated to a fabricated tee with interconnecting mechanical linkage.
3. Performance:
 - a. Process Temperature Rating: Minus 20 to plus 450 deg F.
 - b. ASME B16.34, Class 150 or Class 300.
 - c. Leakage: FCI 70-2, Class IV.
 - d. Rangeability: 300 to 1.
 - e. Rotation: Zero to 90 degrees.
 - f. Equal percentage flow characteristic.
4. Face-to-Face Dimensions: ASME B16.10.
5. Valves NPS 3 through NPS 6: Flanged ends suitable for mating to ASME B16.5 flanges.
6. Body: Carbon steel.
7. Ball and Shaft: Stainless steel.
8. Shaft and Segmented Ball: Pinned and welded.
9. Ball Seat: Graphite.
10. Packing: PTFE V-rings and graphite packing follower.
11. Replaceable seat, ball, and shaft packing.
12. Label each valve with following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Flow directional arrow.

E. Ball Valves with Full Ball and Characterized V-Notch:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Flow-Tek, Inc.
2. Performance:
 - a. Process Temperature Rating: Minus 20 to plus 500 deg F.
 - b. ASME B16.34, Class 600 for NPS 2 and smaller; Class 150 or Class 300 for larger than NPS 2.
 - c. Leakage: FCI 70-2, Class VI, bi-directional.
 - d. Rangeability: Varies from 200 to 1 up to 800 to 1 based on notch pattern of ball.
 - e. Rotation: Zero to 90 degrees.
 - f. Equal percentage flow characteristic.
 - g. Full port.
3. Face-to-Face Dimension: ASME B16.10 long pattern.
4. Valves NPS 2 and Smaller: ASME B1.20.1 threaded (NPT) ends and three-piece body.
5. Valves NPS 2-1/2 through NPS 12: Flanged ends suitable for mating to ASME B16.5 flanges and two-piece body.

6. Hole in the stem slot of each ball equalizes pressure between the body cavity and the line media flow.
7. Replaceable seat, ball, and shaft packing.
8. Body: Carbon steel.
9. Ball and Shaft: Stainless steel.
10. Ball Seat: RPTFE.
11. Stem Seals for Valves NPS 2 and Smaller: Live-loaded, self-adjusting, primary and secondary sealing using belleville washers.
 - a. Primary Seal: Combination of thrust washer and thrust washer protector.
 - b. Secondary Seal: Adjustable stem packing composed of RPTFE V-rings.
12. Stem Seals for Valves Larger than NPS 2: Independent packing gland, adjusted without removing mounting hardware or operator, and contoured to uniformly distribute load across packing.
 - a. Primary Seal: Combination of thrust washer and thrust washer protector.
 - b. Secondary Seal: Adjustable stem packing composed of RPTFE V-rings.
13. Label each valve with following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Flow directional arrow.

F. Industrial-Grade Ball Valves:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Fisher Valves & Instruments; Emerson Process Management.
2. Performance:
 - a. Process Temperature Rating: Minus 20 to plus 450 deg F.
 - b. ASME B16.34, Class 150 or Class 300.
 - c. Leakage: FCI 70-2, Class VI.
 - d. Rangeability: 300 to 1.
 - e. Rotation: Zero to 90 degrees.
 - f. Modified equal percentage flow characteristic.
3. Face-to-Face Dimensions: Comply with ASME B16.10 short pattern.
4. Body: Cast steel ASTM A 216/A 216M WCB.
5. Flanged Body: Suitable for mating to ASME B16.5 flanges.
6. Shaft: 316 stainless-steel ball, 17-4 PH stainless steel.
7. Ball Seat: Reinforced PTFE.
8. PTFE V-ring packing, 316 stainless-steel packing follower.
9. Replaceable seat, ball, and shaft packings.
10. Replaceable 316 stainless-steel shaft bushings with PTFE linings.
11. Corrosion-resistant nameplate indicating the following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Body and trim materials.
 - d. Trim type.
 - e. Body and flange rating.
 - f. Arrow indicating direction of flow.

G. Pressure-Independent Ball Valves NPS 2 and Smaller:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Belimo Aircontrols (USA), Inc.
2. Performance:
 - a. Pressure Rating: 600 psig for NPS 1 and 400 psig for NPS 1-1/2 and NPS 2.
 - b. Close-off pressure of 200 psig.
 - c. Process Temperature Range: Between zero to 212 deg F.
 - d. Rangeability: 100 to 1.
3. Integral Pressure Regulator: Located upstream of ball to regulate pressure, to maintain a constant pressure differential while operating within a pressure differential range of 5 to 50 psig.
4. Body: Forged brass, nickel plated, and with threaded ends.
5. Ball: Chrome-plated brass.
6. Stem and Stem Extension: Chrome-plated brass, blowout-proof design.
7. Stem sleeve or other approved means to allow valve to be opened and closed without damaging field-applied insulation and insulation vapor barrier seal.
8. Ball Seats: Reinforced PTFE.
9. Stem Seal: Reinforced PTFE packing ring stem seal with threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if equivalent cycle endurance can be achieved.
10. Flow Characteristic: Equal percentage.

2.3 BUTTERFLY-STYLE CONTROL VALVES

A. Commercial-Grade, Two-Way Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Keystone; Emerson Electric Co.
2. Performance:
 - a. Bi-directional bubble tight shutoff at 250 psig.
 - b. Comply with MSS SP-67 or MSS SP-68.
 - c. Rotation: Zero to 90 degrees.
 - d. Linear or modified equal percentage flow characteristic.
3. Body: Cast iron ASTM A 126, Class B, ductile iron ASTM A 536 or cast steel ASTM A 216/A 216M WCB fully lugged, suitable for mating to ASME B16.5 flanges.
4. Disc: 316 stainless steel.
5. Shaft: 316 or 17-4 PH stainless steel.
6. Seat: Reinforced EPDM or reinforced PTFE with retaining ring.
7. Shaft Bushings: Reinforced PTFE or stainless steel.
8. Replaceable seat, disc, and shaft bushings.
9. Corrosion-resistant nameplate indicating:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Body and trim materials.
 - d. Flow arrow.

B. Commercial-Grade, Three-Way Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Keystone; Emerson Electric Co.
2. Arrangement: Two valves mated to a fabricated tee with interconnecting mechanical linkage.
3. Performance:
 - a. Bi-directional bubble tight shutoff at 250 psig.
 - b. Comply with MSS SP-67 or MSS SP-68.
 - c. Rotation: Zero to 90 degrees.
 - d. Linear or modified equal percentage flow characteristic.
4. Body: Cast iron ASTM A 126, Class B, ductile iron ASTM A 536 or cast steel ASTM A 216/A 216M WCB fully lugged, suitable for mating to ASME B16.5 flanges.
5. Disc: 316 stainless steel.
6. Shaft: 316 or 17-4 PH stainless steel.
7. Seat: Reinforced EPDM or reinforced PTFE seat with retaining ring.
8. Shaft Bushings: Reinforced PTFE or stainless steel.
9. Replaceable seat, disc, and shaft bushings.
10. Corrosion-resistant nameplate indicating:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body size.
 - c. Body and trim materials.
 - d. Flow arrow.

C. Industrial-Grade Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Fisher Valves & Instruments; Emerson Process Management.
2. Performance:
 - a. Process Temperature Rating: Minus 200 to plus 849 deg F.
 - b. ASME B16.34, Class 150 or Class 300 for larger sizes.
 - c. Complies with MSS SP-68.
 - d. Leakage: FCI 70-2, Class VI, bi-directional.
 - e. Rangeability: 100 to 1.
 - f. Rotation: Zero to 90 degrees.
 - g. Linear or modified equal percentage flow characteristic.
3. Body: Cast steel ASTM A 216/A 216M WCB, fully lugged, suitable for mating to ASME B16.5 flanges.
4. Disc: ASTM A 351/A 351M, CF3M or CF8M stainless steel.
5. Shaft: 17-4 PH stainless steel.
6. Seat: Reinforced PTFE with retaining ring.
7. Shaft Bushings: Reinforced PTFE or stainless steel.
8. Replaceable seat, disc, and shaft bushings.
9. Corrosion-resistant nameplate indicating:
 - a. Manufacturer's name, model number, and serial number.

- b. Body size.
- c. Body and trim materials.
- d. Body rating.
- e. Arrow indicating direction of flow.

2.4 GLOBE-STYLE CONTROL VALVES

A. General Globe-Style Valve Requirements:

- 1. Globe-style control valve body dimensions shall comply with ISA 75.08.01.
- 2. Construct the valves to be serviceable from the top.
- 3. For cage guided valves, trim shall be field interchangeable for different valve flow characteristics, such as equal percentage, linear, and quick opening.
- 4. Reduced trim for one nominal size smaller shall be available for industrial valves NPS 1 and larger.
- 5. Replaceable seats and plugs.
- 6. Furnish each control valve with a corrosion-resistant nameplate indicating the following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body and trim size.
 - c. Arrow indicating direction of flow.

B. Two-Way Globe Valves NPS 2-1/2 to NPS 6:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Johnson Controls, Inc.
 - b. Siemens Industry, Inc., Building Technologies Division.
- 2. Globe Style: Single port.
- 3. Body: Cast iron complying with ASME B61.1, Class 125.
- 4. End Connections: Flanged, suitable for mating to ASME B16.5, Class 150 flanges.
- 5. Bonnet: Bolted.
- 6. Packing: PTFE cone-ring.
- 7. Plug: Top or bottom guided.
- 8. Plug, Seat, and Stem: Brass or stainless steel.
- 9. Process Temperature Rating: 35 to 281 deg F.
- 10. Leakage: 0.1 percent of maximum flow.
- 11. Rangeability: Varies with valve size between 6 and 10 to 1.
- 12. Modified linear flow characteristic.

C. Three-Way Globe Valves NPS 2-1/2 to NPS 6:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Johnson Controls, Inc.
 - b. Siemens Industry, Inc., Building Technologies Division.
- 2. Globe Style: Mix flow pattern.
- 3. Body: Cast iron complying with ASME B61.1, Class 125.
- 4. End Connections: Flanged suitable for mating to ASME B16.5, Class 150 flanges.
- 5. Bonnet: Bolted.
- 6. Packing: PTFE cone-ring.
- 7. Plug: Top or bottom guided.
- 8. Plug, Seat, and Stem: Brass or stainless steel.

9. Process Temperature Rating: 35 to 281 deg F.
10. Leakage: 0.1 percent of maximum flow.
11. Rangeability: Varies with valve size between 6 and 10 to 1.
12. Modified linear flow characteristic.

D. Industrial-Grade Straight-Through Globe Valves NPS 1 and Larger:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Fisher Valves & Instruments; Emerson Process Management.
2. Globe Style: Single port.
3. Body: Cast iron or cast steel.
4. End Connections for NPS 2: Threaded.
5. End Connections for NPS 2-1/2 and Larger: Raised face flanged.
6. Bonnet: Bolted.
7. Packing: PTFE V-ring.
8. Plug: Cage guided and unbalanced.
9. Plug, Seat, and Stem: 416 stainless-steel plug and seat, 17-4 PH stainless-steel cage and 316 stainless-steel stem.
10. Valve Stem: Thread and pin stem to plug.
11. Valve Stem Finish: Polished to 5 microinches rms or less.
12. Plug and Seat Surfaces: Hardened facing.
13. Process Temperature Range: Zero to 450 deg F.
14. Ambient Operating Temperature: Minus 20 to plus 150 deg F.
15. Flow Characteristic: Equal percentage.

2.5 SOLENOID VALVES

A. Manufacturers: Subject to compliance with requirements, undefined:

1. ASCO Valve, Inc.

B. Description:

1. Action: Either normally open or normally closed in the event of electrical power failure as required by the application.
2. Size to close against the system pressure.
3. Manual override capable.
4. Heavy-duty assembly.
5. Body: Brass.
6. Seats and Discs: NBR or PTFE.
7. Solenoid Enclosure: NEMA 250, Type 4.

2.6 ELECTRIC AND ELECTRONIC CONTROL VALVE ACTUATORS

A. Manufacturers: Subject to compliance with requirements, undefined:

1. Belimo Aircontrols (USA), Inc.
2. Honeywell.
3. Johnson Controls, Inc.
4. Siemens Industry, Inc., Building Technologies Division.
5. Valve Solutions, Inc.

- B. Actuators for Hydronic Control Valves: Capable of closing valve against system pump shutoff head.
- C. Actuators for Steam Control Valves: Shutoff against 1.5 times steam design pressure.
- D. Position indicator and graduated scale on each actuator.
- E. Type: Motor operated, with or without gears, electric and electronic.
- F. Voltage: 24-V ac.
- G. Deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
- H. Function properly within a range of 85 to 120 percent of nameplate voltage.
- I. Construction:
 - 1. For Actuators Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
- J. Field Adjustment:
 - 1. Spring Return Actuators: Easily switchable from fail open to fail closed in the field without replacement.
 - 2. Gear Type Actuators: External manual adjustment mechanism to allow manual positioning when the actuator is not powered.
- K. Modulating Actuators:
 - 1. Operation: Capable of stopping at all points across full range, and starting in either direction from any point in range.
 - 2. Control Input Signal:
 - a. Three Point, Tristate, or Floating Point: Clockwise and counter-clockwise inputs. One input drives actuator to open position and other input drives actuator to close position. No signal of either input remains in last position.
 - b. Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for zero- to 10- or 2- to 10-V dc and 4- to 20-mA signals.
 - c. Pulse Width Modulation (PWM): Actuator drives to a specified position according to pulse duration (length) of signal from a dry contact closure, triac sink, or source controller.
 - d. Programmable Multi-Function:
 - 1) Control Input, Position Feedback, and Running Time: Factory or field programmable.
 - 2) Diagnostic: Feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
 - 3) Service Data: Include, at a minimum, number of hours powered and number of hours in motion.
- L. Position Feedback:
 - 1. Where indicated, equip two-position actuators with limits switches or other positive means of a position indication signal for remote monitoring of open and close position.
 - 2. Where indicated, equip modulating actuators with a position feedback through current or voltage signal for remote monitoring.

3. Provide a position indicator and graduated scale on each actuator indicating open and closed travel limits.

M. Fail-Safe:

1. Where indicated, provide actuator to fail to an end position.
2. Internal spring return mechanism to drive controlled device to an end position (open or close) on loss of power.
3. Batteries, capacitors, and other non-mechanical forms of fail-safe operation are acceptable only where uniquely indicated.

N. Integral Overload Protection:

1. Provide against overload throughout the entire operating range in both directions.
2. Electronic overload, digital rotation sensing circuitry, mechanical end switches, or magnetic clutches are acceptable methods of protection.

O. Valve Attachment:

1. Unless otherwise required for valve interface, provide an actuator designed to be directly coupled to valve shaft without the need for connecting linkages.
2. Attach actuator to valve drive shaft in a way that ensures maximum transfer of power and torque without slippage.
3. Bolt and set screw method of attachment is acceptable only if provided with at least two points of attachment.

P. Temperature and Humidity:

1. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of minus 20 to plus 120 deg F.
2. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from 5 to 95 percent relative humidity, non-condensing.

Q. Enclosure:

1. Suitable for ambient conditions encountered by application.
2. NEMA 250, Type 2 for indoor and protected applications.
3. NEMA 250, Type 4 or Type 4X for outdoor and unprotected applications.
4. Provide actuator enclosure with heater and control where required by application.

R. Stroke Time:

1. Operate valve from fully closed to fully open within 90 seconds.
2. Operate valve from fully open to fully closed within 90 seconds.
3. Move valve to failed position within 30 seconds.
4. Select operating speed to be compatible with equipment and system operation.

S. Sound:

1. Spring Return: 62 dBA.
2. Non-Spring Return: 45 dBA.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for valves installed in piping to verify actual locations of piping connections before installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy most stringent requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Provide ceiling, floor, roof, and wall openings and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- D. Firestop penetrations made in fire-rated assemblies and seal penetrations made in acoustically rated assemblies.
- E. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that will cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- F. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- G. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they will be subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments, including, but not limited to, the following:
 - a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
 - 3. Use Type 316 stainless-steel tubing and fittings when in contact with a corrosive environment.
 - 4. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 - 5. Where control devices are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 CONTROL VALVES

- A. Install pipe reducers for valves smaller than line size. Position reducers as close to valve as possible but at distance to avoid interference and impact to performance. Install with manufacturer-recommended clearance.
- B. Install flanges or unions to allow drop-in and -out valve installation.
- C. Valve Orientation:
 - 1. Where possible, install globe and ball valves installed in horizontal piping with stems upright and not more than 15 degrees off of vertical, not inverted.
 - 2. Install valves in a position to allow full stem movement.
 - 3. Where possible, install butterfly valves that are installed in horizontal piping with stems in horizontal position and with low point of disc opening with direction of flow.
- D. Clearance:
 - 1. Locate valves for easy access and provide separate support of valves that cannot be handled by service personnel without hoisting mechanism.
 - 2. Install valves with at least 12 inches of clear space around valve and between valves and adjacent surfaces.
- E. Threaded Valves:
 - 1. Note internal length of threads in valve ends, and proximity of valve internal seat or wall, to determine how far pipe should be threaded into valve.
 - 2. Align threads at point of assembly.
 - 3. Apply thread compound to external pipe threads, except where dry seal threading is specified.
 - 4. Assemble joint, wrench tight. Apply wrench on valve end as pipe is being threaded.
- F. Flanged Valves:
 - 1. Align flange surfaces parallel.
 - 2. Assemble joints by sequencing bolt tightening to make initial contact of flanges and gaskets as flat and parallel as possible. Use suitable lubricants on bolt threads. Tighten bolts gradually and uniformly with a torque wrench.

3.5 CONNECTIONS

- A. Connect electrical devices and components to electrical grounding system. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.6 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with valve identification on valve.

3.7 CLEANING

- A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.
- B. Wash and shine glazing.
- C. Polish glossy surfaces to a clean shine.

3.8 CHECKOUT PROCEDURES

- A. Control Valve Checkout:
 - 1. Check installed products before continuity tests, leak tests, and calibration.
 - 2. Check valves for proper location and accessibility.
 - 3. Check valves for proper installation for direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
 - 4. For pneumatic products, verify air supply for each product is properly installed.
 - 5. For pneumatic valves, verify that pressure gauges are provided in each air line to valve actuator and positioner.
 - 6. Verify that control valves are installed correctly for flow direction.
 - 7. Verify that valve body attachment is properly secured and sealed.
 - 8. Verify that valve actuator and linkage attachment are secure.
 - 9. Verify that actuator wiring is complete, enclosed, and connected to correct power source.
 - 10. Verify that valve ball, disc, and plug travel are unobstructed.
 - 11. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.

3.9 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed back to 100 percent open.
- B. Stroke control valves with pilot positioners. Adjust valve and positioner following manufacturer's recommended procedure, so valve is 100 percent closed, 50 percent closed, and 100 percent open at proper air pressures.
- C. Check and document open and close cycle times for applications with a cycle time of less than 30 seconds.

- D. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

END OF SECTION 230923.11

SECTION 230923.12 - CONTROL DAMPERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes the following types of control dampers and actuators for DDC systems:
 - 1. Rectangular control dampers.
 - 2. Round control dampers.
 - 3. General control-damper actuator requirements.
 - 4. Electric and electronic actuators.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.12.

1.3 DEFINITIONS

- A. DDC: Direct-digital control.
- B. RMS: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 3. Product description with complete technical data, performance curves, and product specification sheets.
 - 4. Installation instructions, including factors affecting performance.
- B. Shop Drawings:
 - 1. Include plans, elevations, sections, and[mounting] details.

2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include diagrams for air and process signal tubing.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 1. Product installation location shown in relationship to room, duct, and equipment.
 2. Size and location of wall access panels for control dampers and actuators installed behind walls.
 3. Size and location of ceiling access panels for control dampers and actuators installed above inaccessible ceilings.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For control dampers to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASME Compliance: Fabricate and label products to comply with ASME Boiler and Pressure Vessel Code where required by authorities having jurisdiction.
- C. Ground Fault: Products shall not fail due to ground fault condition when suitably grounded.
- D. Backup Power Source: Systems and equipment served by a backup power source shall have associated control damper actuators served from a backup power source.
- E. Environmental Conditions:
 1. Provide electric control-damper actuators, with protective enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Electric control-damper actuators not available with integral enclosures, complying with requirements indicated, shall be housed in protective secondary enclosures.
 - a. Hazardous Locations: Explosion-proof rating for condition.

2.2 RECTANGULAR CONTROL DAMPERS

A. General Requirements:

1. Unless otherwise indicated, use parallel blade configuration for two-position control, equipment isolation service, and when mixing two airstreams. For other applications, use opposed blade configuration.
2. Factory-assemble multiple damper sections to provide a single damper assembly of size required by the application.
3. Damper actuator shall be factory installed by damper manufacturer as integral part of damper assembly. Coordinate actuator location and mounting requirements with damper manufacturer.

B. Rectangular Dampers with Aluminum Airfoil Blades:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Ruskin Company.
2. Performance:
 - a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-in. wg differential static pressure.
 - b. Pressure Drop: 0.05-in. wg at 1500 fpm across a 24-by-24-inch damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to 6000 fpm.
 - d. Temperature: Minus 40 to plus 185 deg F.
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
 - f. Damper shall have AMCA seal for both air leakage and air performance.
3. Construction:
 - a. Frame:
 - 1) Material: ASTM B 211, Alloy 6063 T5 extruded-aluminum profiles, 0.07 inch thick.
 - 2) Hat-shaped channel with integral flange(s). Mating face shall be a minimum of 1 inch.
 - 3) Width not less than 5 inches.
 - b. Blades:
 - 1) Hollow, airfoil, extruded aluminum.
 - 2) Parallel or opposed blade configuration as required by application.
 - 3) Material: ASTM B 211, Alloy 6063 T5 aluminum, 0.07 inch thick.
 - 4) Width not to exceed 6 inches.
 - 5) Length as required by close-off pressure, not to exceed 48 inches.
 - c. Seals:
 - 1) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
 - 2) Jambs: Stainless steel, compression type.
 - d. Axles: 0.5-inch- diameter [plated] [or] [stainless] steel, mechanically attached to blades.
 - e. Bearings:

- 1) Molded synthetic or stainless-steel sleeve mounted in frame.
 - 2) Where blade axles are installed in vertical position, provide thrust bearings.
 - f. Linkage:
 - 1) Concealed in frame.
 - 2) Constructed of aluminum and [plated] [or] [stainless] steel.
 - 3) Hardware: Stainless steel.
 - g. Transition:
 - 1) For round and flat oval duct applications, provide damper assembly with integral transitions to mate to adjoining field connection.
 - 2) Factory mount damper in a sleeve with a close transition to mate to field connection.
 - 3) Damper size and sleeve shall be connection size plus 2 inches.
 - 4) Sleeve length shall be not less than 12 inches for dampers without jackshafts and shall be not less than 16 inches for dampers with jackshafts.
 - 5) Sleeve material shall match adjacent duct.
 - h. Additional Corrosion Protection for Corrosive Environments:
 - 1) Provide anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of 0.0007 inch thick.
 - 2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.
4. Airflow Control:
 - a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Ebtron, Inc.
 - 2) Ruskin Company.
 - b. Where indicated, provide damper assembly with integral airflow measurement and control.
 - c. A factory-furnished and -calibrated controller shall be programmed, in nonvolatile EPROM, with application-specific airflow set point and range.
 - d. The controller and actuator shall communicate to control the desired airflow.
 - e. The controller shall receive a zero- to 10-V dc input signal and report a zero- to 20-mA output signal that is proportional to the airflow.
 - f. Airflow measurement and control range shall be suitable for operation between 150 to 2000 fpm.
 - g. Ambient Operating Temperature Range: Minus 40 to plus 140 deg F.
 - h. Ambient Operating Humidity Range: 5 to 95 percent relative humidity, non-condensing.
 - i. Provide unit with control transformer rated for not less than 85 VA. Provide transformer with primary and secondary protection and primary disconnecting means. Coordinate requirements with field power connection.
 - j. Provide screw terminals for interface to field wiring.
 - k. Factory mount electronics within a NEMA 250, Type 1 painted steel enclosure.

C. Rectangular Dampers with Steel Airfoil Blades:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Ruskin Company.

2. Performance:
 - a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-in. wg differential static pressure.
 - b. Pressure Drop: 0.06-in. wg at 1500 fpm across a 24-by-24-inch damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to 6000 fpm.
 - d. Temperature: Minus 40 to plus 185 deg F.
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
 - f. Damper shall have AMCA seal for both air leakage and air performance.
3. Construction:
 - a. Frame:
 - 1) Material: ASTM A 653/A 653M galvanized-steel profiles, 0.06 inch thick.
 - 2) Hat-shaped channel with integral flanges. Mating face shall be a minimum of 1 inch.
 - 3) Width not less than 5 inches.
 - b. Blades:
 - 1) Hollow, airfoil, galvanized steel.
 - 2) Parallel or opposed blade configuration as required by application.
 - 3) Material: ASTM A 653/A 653M galvanized steel, 0.05 inch thick.
 - 4) Width not to exceed 6 inches.
 - 5) Length as required by close-off pressure, not to exceed 48 inches.
 - c. Seals:
 - 1) Blades: Replaceable, mechanically attached extruded silicone, vinyl, or plastic composite.
 - 2) Jambs: Stainless steel, compression type.
 - d. Axles: 0.5-inch- diameter [plated] [or] [stainless] steel, mechanically attached to blades.
 - e. Bearings:
 - 1) Stainless steel mounted in frame.
 - 2) Where blade axles are installed in vertical position, provide thrust bearings.
 - f. Linkage:
 - 1) Concealed in frame.
 - 2) Constructed of aluminum and [plated] [or] [stainless] steel.
 - 3) Hardware: Stainless steel.
 - g. Transition:
 - 1) For round and flat oval duct applications, provide damper assembly with integral transitions to mate to adjoining field connection.
 - 2) Factory mount damper in a sleeve with a close transition to mate to field connection.
 - 3) Damper size and sleeve shall be connection size plus 2 inches.
 - 4) Sleeve length shall be not less than 12 inches for dampers without jackshafts and shall be not less than 16 inches for dampers with jackshafts.
 - 5) Sleeve material shall match adjacent duct.

- h. Additional Corrosion Protection for Corrosive Environments:
 - 1) Provide epoxy finish for surfaces in contact with airstream.
 - 2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.

D. Rectangular Dampers with Aluminum Flat Blades:

- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Ruskin Company.
- 2. Performance:
 - a. Leakage: Leakage shall not exceed 3.2 cfm/sq. ft. against 1-in. wg differential static pressure.
 - b. Pressure Drop: 0.07-in. wg at 1500 fpm across a 24-by-24-inch damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to 2000 fpm.
 - d. Temperature: Minus 50 to plus 250 deg F.
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length, not to exceed 3-in. wg.
 - f. Damper shall have AMCA seal for both air leakage and air performance.
- 3. Construction:
 - a. Frame:
 - 1) Material: ASTM B 211, Alloy 6063 T5 extruded-aluminum profiles, 0.12 inch thick.
 - 2) Hat-shaped channel[with integral flanges].
 - 3) Width not less than 5 inches.
 - b. Blades:
 - 1) Flat blades of extruded aluminum.
 - 2) Parallel or opposed blade configuration as required by application.
 - 3) Material: ASTM B 211, Alloy 6063 T5 extruded-aluminum profiles, 0.12 inch thick.
 - 4) Width not to exceed 6 inches.
 - 5) Length as required by close-off pressure, not to exceed 48 inches.
 - c. Seals:
 - 1) Blades: Replaceable, mechanically attached extruded silicone, vinyl or plastic composite.
 - 2) Jambs: Stainless steel, compression type.
 - d. Axles: 0.5-inch-diameter plated or stainless steel, mechanically attached to blades.
 - e. Bearings:
 - 1) Molded-synthetic sleeve, mounted in frame.
 - 2) Where blade axles are installed in vertical position, provide thrust bearings.
 - f. Linkage:
 - 1) Concealed in frame.

- 2) Constructed of plated or stainless steel.
- 3) Hardware: Stainless steel.

g. Transition:

- 1) For round and flat oval duct applications, provide damper assembly with integral transitions to mate to adjoining field connection.
- 2) Factory mount damper in a sleeve with a close transition to mate to field connection.
- 3) Damper size and sleeve shall be connection size plus 2 inches.
- 4) Sleeve length shall be not less than 12 inches for dampers without jackshafts and shall be not less than 16 inches for dampers with jackshafts.
- 5) Sleeve material shall match adjacent duct.

h. Additional Corrosion Protection for Corrosive Environments:

- 1) Provide anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of 0.0007 inch thick.
- 2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.

E. Rectangular Dampers with Steel Flat Blades:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

- a. Ruskin Company.

2. Performance:

- a. Leakage: Leakage shall not exceed 4.8 cfm/sq. ft. against 1-in. wg differential static pressure.
- b. Pressure Drop: 0.1-in. wg at 1500 fpm across a 24-by-24-inch damper when tested according to AMCA 500-D, figure 5.3.
- c. Velocity: Up to 1500 fpm.
- d. Temperature: Minus 25 to plus 180 deg F.
- e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length, not to exceed 4-in. wg.
- f. Damper shall have AMCA seal for both air leakage and air performance.

3. Construction:

a. Frame:

- 1) Material: Galvanized or stainless steel, 0.06 inch thick.
- 2) Hat-shaped channel with integral flanges.
- 3) Width not less than 5 inches.

b. Blades:

- 1) Flat blades with multiple grooves positioned axially for reinforcement.
- 2) Parallel or opposed blade configuration as required by application.
- 3) Material: Galvanized or stainless steel, 0.06 inch thick.
- 4) Width not to exceed 6 inches.
- 5) Length as required by close-off pressure, not to exceed 48 inches.

c. Seals:

- 1) Blades: Replaceable, mechanically attached, PVC-coated polyester.
 - 2) Jambs: Stainless steel, compression type.
 - d. Axles: 0.5-inch- diameter plated or stainless steel, mechanically attached to blades.
 - e. Bearings:
 - 1) Molded-synthetic sleeve, mounted in frame.
 - 2) Where blade axles are installed in vertical position, provide thrust bearings.
 - f. Linkage:
 - 1) Concealed in frame.
 - 2) Constructed of plated or stainless steel.
 - 3) Hardware: Stainless steel.
- F. Insulated Rectangular Dampers:
 1. Performance:
 - a. Leakage: AMCA 511, Class 1A. Leakage shall not exceed 3 cfm/sq. ft. against 1-in. wg differential static pressure and shall not exceed 4.9 cfm/sq. ft. against 4-in. wg differential static pressure at minus 40 deg F.
 - b. Pressure Drop: 0.1-in. wg at 1500 fpm across a 24-by-24-inch damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to 4000 fpm.
 - d. Temperature: Minus 100 to plus 185 deg F.
 - e. Pressure Rating: Damper close-off pressure equal to fan shutoff pressure with a maximum blade deflection of 1/200 of blade length.
 - f. Damper shall have AMCA seal for both air leakage and air performance.
 2. Construction:
 - a. Frame:
 - 1) Material: ASTM B 211, Alloy 6063 T5 extruded-aluminum profiles, 0.08 inch thick.
 - 2) C-shaped channel with integral flange(s). Mating face shall be a minimum of 1 inch.
 - 3) Width not less than 4 inches.
 - 4) Entire frame shall be thermally broken by means of polyurethane resin pockets, complete with thermal cuts.
 - 5) Damper frame shall be insulated with polystyrofoam on four sides.
 - b. Blades:
 - 1) Hollow shaped, extruded aluminum.
 - 2) Blades shall be internally insulated with expanded polyurethane foam and shall be thermally broken. Complete blade shall have an insulating factor of R-2.29 and a temperature index of 55.
 - 3) Parallel or opposed blade configuration as required by application.
 - 4) Material: ASTM B 211, Alloy 6063 T5 aluminum, 0.08 inch thick.
 - 5) Width not to exceed 6 inches.
 - 6) Length as required by close-off pressure, not to exceed 48 inches.
 - c. Seals: Blade and frame seals shall be of flexible silicone and secured in an integral slot within the aluminum extrusions.
 - d. Axles: 0.44-inch- diameter [plated] [or] [stainless] steel, mechanically attached to blades.

- e. Bearings:
 - 1) Bearings shall be composed of a Celcon inner bearing fixed to axle, rotating within a polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact.
 - 2) Where blade axles are installed in vertical position, provide thrust bearings.
- f. Linkage:
 - 1) Concealed in frame.
 - 2) Constructed of aluminum and [plated] [or] [stainless] steel.
 - 3) Hardware: Stainless steel.
- g. Transition:
 - 1) For round and flat oval duct applications, provide damper assembly with integral transitions to mate to adjoining field connection.
 - 2) Factory mount damper in a sleeve with a close transition to mate to field connection.
 - 3) Damper size and sleeve shall be connection size plus 2 inches.
 - 4) Sleeve length shall be not less than 12 inches for dampers without jackshafts and shall be not less than 16 inches for dampers with jackshafts.
 - 5) Sleeve material shall match adjacent duct.
- h. Additional Corrosion Protection for Corrosive Environments:
 - 1) Provide anodized finish for aluminum surfaces in contact with airstream. Anodized finish shall be a minimum of 0.0007 inch thick.
 - 2) Axles, damper linkage, and hardware shall be constructed of Type 316L stainless steel.

2.3 ROUND CONTROL DAMPERS

A. Round Dampers, Sleeve Type:

- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Ruskin Company.
- 2. Performance:
 - a. Leakage: Leakage shall not exceed 0.15 cfm/in. of perimeter blade at 4-in. wg differential static pressure.
 - b. Pressure Drop: 0.02-in. wg at 1500 fpm across a 12-inch damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to 4000 fpm.
 - d. Temperature: Minus 25 to plus 200 deg F.
 - e. Pressure Rating: 8-in. wg for sizes through 12 inches, 6-in. wg for larger sizes.
- 3. Construction:
 - a. Frame:
 - 1) Material: Galvanized or stainless steel, 0.04 in thick.
 - 2) Outward rolled stiffener beads positioned approximately 1 inch inboard of each end.

- 3) Sleeve-type connection for mating to adjacent ductwork.
 - 4) Size Range: 4 to 24 inches.
 - 5) Length not less than 7 inches.
 - 6) Provide 2-inch sheet metal stand-off for mounting actuator.
- b. Blade: Double-thickness circular flat blades sandwiched together and constructed of galvanized or stainless steel.
 - c. Blade Seal: Polyethylene foam seal sandwiched between two sides of blades and fully encompassing blade edge.
 - d. Axle: 0.5-inch- diameter [plated] [or] [stainless] steel, mechanically attached to blade.
 - e. Bearings: Stainless-steel sleeve pressed into frame.

B. Round Dampers, Flanged Type:

- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Ruskin Company.
- 2. Performance:
 - a. Leakage: Leakage shall not exceed 0.15 cfm/in. of perimeter blade at 4-in. wg differential static pressure.
 - b. Pressure Drop: 0.03-in. wg at 1500 fpm across a 12-inch damper when tested according to AMCA 500-D, figure 5.3.
 - c. Velocity: Up to 4000 fpm.
 - d. Temperature: Minus 25 to plus 250 deg F.
 - e. Pressure Rating: 8-in. wg for sizes through 36 inches in diameter, 6-in. wg for larger sizes.
- 3. Construction:
 - a. Frame:
 - 1) Size Range: 4 to 60 inches.
 - 2) Material: Galvanized or stainless steel.
 - a) Sizes through 24 Inches in Diameter: 0.15 inch thick.
 - b) Sizes 26 through 48 Inches in Diameter: 0.25 inch thick.
 - c) Larger Sizes: 0.31 inch thick.
 - 3) Flanges:
 - a) Outward rolled with bolt holes on each end of frame for mating to adjacent ductwork.
 - b) Face: Not less than 1.25 inch for damper sizes through 12 inches in diameter, 1.5 inch for damper sizes 14 through 24 inches in diameter, and 2 inches for larger sizes.
 - 4) Length (Flange Face to Face): Not less than 8 inches.
 - 5) Provide 3-inch sheet metal stand-off for mounting actuator.
 - b. Blade: Reinforced circular flat blade constructed of galvanized or stainless steel.
 - 1) Sizes through 24 Inches: 0.15 inch thick.
 - 2) Sizes 26 through 48 Inches: 0.19 inch thick.
 - 3) Larger Sizes: 0.25 inch thick.

- c. Blade Stop: Full circumference, located in airstream, minimum 0.5 by 0.25 inch galvanized or stainless steel bar.
- d. Blade Seal: Neoprene, mechanically attached to blade and fully encompassing blade edge.
- e. Axle: Plated or stainless steel, mechanically attached to blade.
 - 1) Sizes through 14 Inches: 0.5 inch in diameter.
 - 2) Sizes 16 through 42 Inches: 0.75 inch in diameter.
 - 3) Larger Sizes: 1 inch in diameter.
- f. Bearings: Stainless-steel sleeve pressed into frame.

2.4 GENERAL CONTROL-DAMPER ACTUATORS REQUIREMENTS

- A. Actuators shall operate related damper(s) with sufficient reserve power to provide smooth modulating action or two-position action and proper speed of response at velocity and pressure conditions to which the damper is subjected.
- B. Actuators shall produce sufficient power and torque to close off against the maximum system pressures encountered. Actuators shall be sized to close off against the fan shutoff pressure as a minimum requirement.
- C. The total damper area operated by an actuator shall not exceed 80 percent of manufacturer's maximum area rating.
- D. Provide one actuator for each damper assembly where possible. Multiple actuators required to drive a single damper assembly shall operate in unison.
- E. Avoid the use of excessively oversized actuators which could overdrive and cause linkage failure when the damper blade has reached either its full open or closed position.
- F. Use jackshafts and shaft couplings in lieu of blade-to-blade linkages when driving axially aligned damper sections.
- G. Provide mounting hardware and linkages for connecting actuator to damper.
- H. Select actuators to fail in desired position in the event of a power failure.
- I. Actuator Fail Positions:[See Drawings.][As indicated below:]
 - 1. Exhaust Air: [Close] [Last position] [Open].
 - 2. Outdoor Air: [Close] [Last position] [Open].
 - 3. Supply Air: [Close] [Last position] [Open].
 - 4. Return Air: [Close] [Last position] [Open].
 - 5. <Insert system and fail position>.

2.5 TERMINAL UNIT DAMPER ACTUATORS

- A. For terminal units that have an exposed damper shaft the terminal unit controller shall have an integral damper actuator that shall be a fast response stepper motor capable of stroking 90 degrees in 30 seconds for quick damper positioning to speed commissioning and troubleshooting tasks.
- B. Type: Motor operated, with or without gears, electric and electronic.
- C. Voltage:

1. 24 V.
2. Actuator shall deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
3. Actuator shall function properly within a range of 85 to 120 percent of nameplate voltage.

D. Construction:

1. Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
2. 100 up to 400 W: Gears ground steel, oil immersed, shaft-hardened steel running in bronze, copper alloy, or ball bearings. Operator and gear trains shall be totally enclosed in dustproof cast-iron, cast-steel, or cast-aluminum housing.
3. Greater Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.

E. Field Adjustment:

1. Spring return actuators shall be easily switchable from fail open to fail closed in the field without replacement.
2. Provide gear-type actuators with an external manual adjustment mechanism to allow manual positioning of the damper when the actuator is not powered.

F. Two-Position Actuators: Single direction, spring return or reversing type.

G. Modulating Actuators:

1. Capable of stopping at all points across full range, and starting in either direction from any point in range.
2. Control Input Signal:
 - a. Three Point, Tristate, or Floating Point: Clockwise and counter-clockwise inputs. One input drives actuator to open position, and other input drives actuator to close position. No signal of either input remains in last position.
 - b. Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for zero- to 10- or 2- to 10-V dc and 4- to 20-mA signals.
 - c. Pulse Width Modulation (PWM): Actuator drives to a specified position according to a pulse duration (length) of signal from a dry-contact closure, triac sink or source controller.
 - d. Programmable Multi-Function:
 - 1) Control input, position feedback, and running time shall be factory or field programmable.
 - 2) Diagnostic feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
 - 3) Service data, including at a minimum, number of hours powered and number of hours in motion.

H. Position Feedback:

1. Where indicated, equip two-position actuators with limits switches or other positive means of a position indication signal for remote monitoring of open and close position.
2. Where indicated, equip modulating actuators with a position feedback through current or voltage signal for remote monitoring.
3. Provide a position indicator and graduated scale on each actuator indicating open and closed travel limits.

- I. Fail-Safe:
 - 1. Where indicated, provide actuator to fail to an end position.
 - 2. Internal spring return mechanism to drive controlled device to an end position (open or close) on loss of power.
 - 3. Batteries, capacitors, and other non-mechanical forms of fail-safe operation are acceptable only where uniquely indicated.
- J. Integral Overload Protection:
 - 1. Provide against overload throughout the entire operating range in both directions.
 - 2. Electronic overload, digital rotation sensing circuitry, mechanical end switches, or magnetic clutches are acceptable methods of protection.
- K. Damper Attachment:
 - 1. Unless otherwise required for damper interface, provide actuator designed to be directly coupled to damper shaft without need for connecting linkages.
 - 2. Attach actuator to damper drive shaft in a way that ensures maximum transfer of power and torque without slippage.
 - 3. Bolt and set screw method of attachment is acceptable only if provided with at least two points of attachment.
- L. Temperature and Humidity:
 - 1. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of off minus 20 to plus 120.
 - 2. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from 5 to 95 percent relative humidity, non-condensing.
- M. Enclosure:
 - 1. Suitable for ambient conditions encountered by application.
 - 2. NEMA 250, Type 2 for indoor and protected applications.
 - 3. NEMA 250, Type 4 or Type 4X for outdoor and unprotected applications.
 - 4. Provide actuator enclosure with a heater and controller where required by application.
- N. Stroke Time:
 - 1. Operate damper from fully closed to fully open within [15] [60] [75] [90] [150] <Insert number> seconds.
 - 2. Operate damper from fully open to fully closed within [15] [60] [75] [90] [150] <Insert number> seconds.
 - 3. Move damper to failed position within [5] [15] [30] <Insert number> seconds.
 - 4. Select operating speed to be compatible with equipment and system operation.
 - 5. Actuators operating in smoke control systems comply with governing code and NFPA requirements.
- O. Sound:
 - 1. Spring Return: 62 dBA.
 - 2. Non-Spring Return: 45 dBA.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for dampers and instruments installed in duct systems to verify actual locations of connections before installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CONTROL-DAMPER APPLICATIONS

- A. Control Dampers:
- B. Select from damper types indicated in "Control Dampers" Article to achieve performance requirements and characteristics indicated while subjected to full range of system operation encountered.
 - 1. Rectangular Outdoor Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: [Rectangular dampers with aluminum airfoil blades] [Rectangular dampers with steel airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Rectangular dampers with steel flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type].
 - 2. Round Outdoor Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: [Rectangular dampers with aluminum airfoil blades] [Rectangular dampers with steel airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Rectangular dampers with steel flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type].
 - 3. Rectangular Return Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: [Rectangular dampers with aluminum airfoil blades] [Rectangular dampers with steel airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Rectangular dampers with steel flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type].
 - 4. Round Return Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: [Rectangular dampers with aluminum airfoil blades] [Rectangular dampers with steel airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Rectangular dampers with steel flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type].
 - 5. Rectangular Supply Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: [Rectangular dampers with aluminum airfoil blades] [Rectangular dampers with steel airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Rectangular dampers with steel flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type].
 - 6. Round Supply Air Duct Applications with SMACNA Construction Class <Insert value> and Velocities to <Insert value>: [Rectangular dampers with aluminum airfoil blades] [Rectangular dampers with steel airfoil blades] [Industrial-duty rectangular dampers with steel airfoil blades] [Rectangular dampers with aluminum flat blades] [Rectangular dampers with steel flat blades] [Insulated rectangular dampers] [Round dampers, sleeve type] [Round dampers, flange type].

3.3 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy most stringent requirements indicated.

- B. Properly support dampers and actuators, tubing, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to a <Insert valve> force.
- C. Provide ceiling, floor, roof, and wall openings and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- D. Seal penetrations made in fire-rated and acoustically rated assemblies.
- E. Fastening Hardware:
 - 1. Stillson wrenches, pliers, or other tools that will cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- F. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- G. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they will be subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments, including, but not limited to, the following:
 - a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
 - 3. Use Type 316 stainless-steel tubing and fittings when in contact with a corrosive environment.
 - 4. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 - 5. Where actuators are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.4 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.5 CONTROL DAMPERS

- A. Install smooth transitions, not exceeding [15] [30] <Insert number> degrees, to dampers smaller than adjacent duct. Install transitions as close to damper as possible but at distance to avoid interference and impact to performance. Consult manufacturer for recommended clearance.
- B. Clearance:
 - 1. Locate dampers for easy access and provide separate support of dampers that cannot be handled by service personnel without hoisting mechanism.
 - 2. Install dampers with at least 24 inches of clear space on sides of dampers requiring service access.
- C. Service Access:
 - 1. Dampers and actuators shall be accessible for visual inspection and service.
 - 2. Install access door(s) in duct or equipment located upstream of damper to allow service personnel to hand clean any portion of damper, linkage, and actuator. Comply with requirements in Section 233300 "Air Duct Accessories."
- D. Install dampers straight and true, level in all planes, and square in all dimensions. Install supplementary structural steel reinforcement for large multiple-section dampers if factory support alone cannot handle loading.
- E. Attach actuator(s) to damper drive shaft.
- F. For duct-mounted and equipment-mounted dampers installed outside of equipment, install a visible and accessible indication of damper position from outside.

3.6 CONNECTIONS

- A. Connect electrical devices and components to electrical grounding system. Comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.7 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with damper identification on damper[and on face of ceiling where damper is concealed above ceiling].

3.8 CHECKOUT PROCEDURES

- A. Control-Damper Checkout:
 - 1. Check installed products before continuity tests, leak tests, and calibration.
 - 2. Check dampers for proper location and accessibility.
 - 3. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.
 - 4. Verify that control dampers are installed correctly for flow direction.
 - 5. Verify that proper blade alignment, either parallel or opposed, has been provided.
 - 6. Verify that damper frame attachment is properly secured and sealed.
 - 7. Verify that damper actuator and linkage attachment are secure.
 - 8. Verify that actuator wiring is complete, enclosed, and connected to correct power source.
 - 9. Verify that damper blade travel is unobstructed.

3.9 ADJUSTMENT, CALIBRATION, AND TESTING:

- A. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 100 percent closed back to 100 percent open.
- B. Stroke control dampers with pilot positioners. Adjust damper and positioner following manufacturer's recommended procedure, so damper is 100 percent closed, 50 percent closed, and 100 percent open at proper air pressure.
- C. Check and document open and close cycle times for applications with a cycle time of less than 30 seconds.
- D. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

END OF SECTION 230923.12

SECTION 230923.13 - ENERGY METERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes thermal and electric power energy meters that connect to DDC systems.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.

1.3 DEFINITIONS

- A. DDC: Direct-digital control.
- B. Ethernet: Local area network based on IEEE 802.3.1 standards.
- C. Firmware: Software (programs or data) that has been written onto read-only memory (ROM). Firmware is a combination of software and hardware. Storage media with ROMs that have data or programs recorded on them are firmware.
- D. I/O: Input/output.
- E. RMS: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.
- F. RS-232: A TIA standard for asynchronous serial data communications between terminal devices.
- G. RS-485: A TIA standard for multipoint communications using two twisted pairs.
- H. RTD: Resistance temperature detector.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics, electrical characteristics, and furnished accessories indicating electrical power requirements.
 - 3. Product description with complete technical data, performance curves, and product specification sheets.

B. Sustainable Design Submittals:

1. Product Data for EA Credit "Advanced Energy Metering": For continuous metering equipment.

C. Shop Drawings:

1. Include plans, elevations, sections, and mounting details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Product Certificates: For each product requiring a certificate.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For energy meters to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 BTU METERS

A. Stand Alone BTU Meters

1. System 10

- a. Description: Provide complete Energy (BTU) Measurement System including micro-processor based BTU meter, flowmeter, matched set of temperature sensors and mechanical installation hardware and cabling required for a complete system installation. BTU measurement system shall be configured for the specific application prior to delivery.

- 1) A certificate of NIST* traceable calibration shall be provided with each system.
- 2) Application: The contractor shall be responsible for selecting the BTU meter options submitted based on the application. BTU meter shall be constructed, calibrated and scaled for the intended application in terms of pipe size, pipe material, installation requirements, expected energy rate, ambient conditions and fluid characteristics which include but are not limited to pressure, temperature and viscosity.
- 3) Enclosure; System 10: Painted steel NEMA 4
- 4) Backlit Alphanumeric displays, energy total, energy rate, flow rate, supply temperature and return temperature. Upon loss of power data will be stored in Non-Volatile EEPROM memory
- 5) Power: 24VAC, 120 VAC, or 230 VAC Provides 24 Vdc @ 200mA power to flow meters and electronics
- 6) BTU meter must be able to be field commissioned for later recalibrations.

- b. Liquid Temperature Sensor & Transmitters:

- 1) Temperature Sensor: Bath-calibrated and matched for the specific temperature range for each application.
- 2) Temperature ranges; 32 to 200° F, , , , OR

- 3) Temperature sensors shall be loop-powered current based (mA) sensors and shall be bath-calibrated and matched (NIST* traceable) for the specific temperature range for each application.
- 4) The calculated differential temperature used in the energy calculation shall be accurate to within +0.15°F (including the error from individual temperature sensors and transmitters matching, input offsets, and calculations).

c. FLOW METER

1) INSERTION TURBINE METER

a) DESCRIPTION

- (1) The flow meter shall have rotating axial turbine/s, with electronic impedance-based sensing and an averaging circuit to reduce measurement errors due to swirl and flow profile distortion.
- (2) The flow meter shall be hand insert-able up to 400 psig.
- (3) Operating temperature of < 280 deg. F, 300 deg. F peak.
- (4) Meter complete with all installation hardware necessary to enable insertion and removal of the meter without system shutdown.
- (5) Each flow meter shall be individually wet-calibrated against a primary volumetric standard that is accurate to within 0.1% of flow rate.
- (6) The manufacturer's NIST traceable certificate of calibration shall be provided with each meter.
- (7) Pressure drop not to exceed < 1.0 psig at 20-fps flow velocity in 1 ½" pipe.

b) Sensor

- (1) The electronics convert the rotational frequency, which is proportional to the velocity of the fluid, to industry standard electrical output signals. (non-magnetic and non-photoelectric).
- (2) Standard wetted components for chilled water/glycol applications and hot water, < 250° F shall be nickel-plated brass.
- (3) Wetted metal components for hot water applications > 250°F and non-metallic pipe installation shall be type 316 Stainless Steel.
- (4) For Pipe Sizes NPS 2.5" (DN 63) and larger: Dual Contra rotating turbine sensors.
- (5) For Pipe sizes NPS 2.25" (DN 57) to 1.25" (DN 19): Single turbine sensors
- (6) Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts.
- (7) Suitable for flow measurement of fluids with electrical conductivity more than 3 micro-Siemens per cm.

c) Transmitter

- (1) Outputs
 - (a) Voltage: 0-10 or 0-5 Vdc
 - (b) Current: 4-20 mA
 - (c) Pulse: 0-15V Square wave pulse output linear with flow rate for connection to optional display or BAS interface
 - (d) Scaled pulse dry contact closure
- (2) House sensor electronics in a weather tight aluminum enclosure.

- (3) Enclosure shall include connection(s) for field-installed conduit.
- (4) 24-Vac/dc power to power the flow sensor.
- (5) Shall have cable of length sufficient to connect to display module.

d) Accuracy

- (1) Shall be within $\pm 0.5\%$ of rate at the calibrated velocity
- (2) $\pm 1\%$ of rate over a 10:1 turndown (3.0 to 30 ft/s)
- (3) $\pm 2\%$ of rate over a 50:1 turndown (from 0.4 to 20 ft/s).

2. System 20

- a. Description: Provide complete Energy (BTU) Measurement System including micro-processor based BTU meter, flowmeter, matched set of temperature sensors and mechanical installation hardware and cabling required for a complete system installation. BTU measurement system shall be configured for the specific application prior to delivery.
- b. A certificate of NIST* traceable calibration shall be provided with each system.
- c. Application: The contractor shall be responsible for selecting the BTU meter options submitted based on the application. BTU meter shall be constructed, calibrated and scaled for the intended application in terms of pipe size, pipe material, installation requirements, expected energy rate, ambient conditions and fluid characteristics which include but are not limited to pressure, temperature and viscosity.
- d. Design: Total thermal energy measurement (BTU) system to be provided by a single manufacturer, including flowmeter, temperature sensors and BTU meter.
 - 1) BTU Calculator: Computation error $\leq 0.09\%$ @ 30-degree F delta T.
 - 2) Enclosure: NEMA 12K enclosure minimum, designed for wall or DIN rail mounting. Non-metallic enclosure materials of construction must meet UL 94 V-0 flammability requirements and be suitable for use in plenum spaces.
 - 3) Connections: Provide three (3) $\frac{1}{2}$ " conduit access holes minimum.
 - 4) Ratings:
 - a) Pressure: N/A
 - b) Temperature: -13 F to 140 F ambient
- e. Operation and Configuration:
 - 1) Flow Meter Accuracy: Accuracy shall be within $\pm 1\%$ of rate from 2-20 ft/s. Overall turndown shall exceed 100:1.
 - 2) Temperature Sensor Accuracy:
 - a) Current (mA) based sensors: Provide a matched pair of loop powered, current (mA) based temperature sensors, wet calibrated over the intended application range against NIST traceable standards. Current (mA) signal shall be unaffected by wire length. Differential temperature measurement uncertainty within calibrated range shall be $\leq$ to ± 0.15 -degree F.
 - b) Resistance Temperature Device (RTD): Provide a matched pair of 1000 Ohm platinum RTDs, wet calibrated to a differential measurement uncertainty of ± 0.18 -degree F over the stated range. RTD's must meet EN1434/C900 accuracy requirements for 3K sensors.
 - 3) Calibration and Configuration: Each thermal energy (BTU) metering system shall be factory programmed for the specific application and each metering system component, including temperature sensors and flow meter, shall receive a certificate of calibration, directly traceable to N.I.S.T.

- 4) Transmitter and Display: Provide an operator interface consisting of four push-buttons and graphical interface. Display shall visually indicate total fluid volume in gallons, instantaneous flow rate, supply temperature, return temperature, thermal energy flow rate and thermal-energy flow total in kilowatts per hour or British thermal units (BTU). Output signals shall be RS485 serial network protocol, native BACnet MS/TP or MODBUS RTU, three (3) programmable pulse outputs and one (1) analog output signal. Meter shall have the capability to receive and totalize three (3) auxiliary input pulses which can be viewed locally and communicated over the RS485 network.
 - f. Listings and Certifications:
 - 1) Meter shall have FCC: Part 15, Subpart B
 - 2) Meter shall have CE approval
 - 3) Meter shall be UL listed
 - 4) Meters selected with BACnet shall have BTL Certification to ASHRAE 135:2016
 - g. Operation and Installation: Installation and operating instructions shall be provided for each BTU system.
 - h. Warranty: Each BTU meter shall be covered by the manufacturer's two-year warranty.
3. System 40
 - a. Description: Complete Thermal Energy (BTU) Measurement System with integral direct beam wetted ultrasonic flow sensor, matched temperature sensors, integral transmitter with remote mounting feature, operator interface with visual display, analog, pulse or serial communications capability or a combination as required by application and a wet calibration certificate – traceable to a recognized international standard.
 - b. Application: This contractor shall be responsible for selecting the energy meter options submitted based on the application. Energy metering system shall be constructed and calibrated for the intended application in terms of pipe size, pipe material, installation requirements, expected flow rate, ambient conditions and fluid characteristics which include but are not limited to pressure, temperature and viscosity.
 - c. Flow Sensing Technology: Direct Beam, Wetted, Transit Time Ultrasonic flow meter with matched transducers, dropped forged corrosion resistant metal body and IP 65 rated transmitter enclosure. Meter shall be designed for direct installation into the piping system.
 - d. Maximum Pressure Rating: 400 psig.
 - e. Maximum Temperature Range: 32 to 250 deg F.
 - f. Temperature Sensors: Insertion-type matched pair of 1000 OHM RTD sensors. Temperature sensors shall be certified and matched to an uncertainty of less than 0.18 deg. F. over the operating range.
 - g. BTU Calculator: Solid-state, integrating-type meter with non-volatile EEPROM solid state memory for totalized data and programming memory, designed for direct pipe mounting.
 - h. Data Output: Output signals shall be either serial network protocol, via pulse, analog output or combination. Pulse output for totalization of energy, British thermal units (BTU) typical.

Optional serial communications output shall be native to the BTU meter, BACnet meters shall be BTL certified, secondary communication gateways shall not be permitted. Information provided via the serial communication network shall include: Energy rate, Energy Total, Flow Rate, Flow Total, both Supply and Return temperatures, and trend including peak values. Serial communication meters shall be able to provide up to three additional auxiliary pulses configured as inputs or outputs.

- i. Calibration: Each thermal energy (Btu) metering system shall be factory programmed for the specific application and each metering system, including temperature sensors and flow meter, shall receive a certificate of calibration, directly traceable to NIST
- j. Calculation Accuracy: Shall be less than or equal to 0.09% of energy rate reading at 30 deg. F.
- k. Integral Display and Operator Interface: Provide an operator interface consisting of three push-buttons. Display shall visually indicate total fluid volume in gallons, instantaneous flow rate, supply temperature, return temperature, thermal energy flow rate and thermal-energy flow total in kilowatts per hour or British thermal units (BTU).
- l. Strainer: Full size of main line piping shall be provided upstream of flowmeter.
- m. Operating Instructions: Include complete instructions with each thermal-energy metering system.
- n. Warranty: Each meter shall be covered by the manufacturer's two-year warranty.

B. Central Energy Plant & Campus Application BTU Meter

- 1. The entire Energy Measurement System shall be built and calibrated by a single manufacturer, and shall consist of a flow meter, two temperature sensors, a BTU meter, temperature thermowells, and all required mechanical installation hardware. A certificate of NIST* traceable calibration shall be provided with each system. All equipment shall be covered by the manufacturer's two year warranty.
- 2. BTU Meter: Provide an ONICON System-10 BTU Meter. The BTU meter shall provide the following points both at the integral LCD and as outputs to the building control system: Energy Total, Energy Rate, Flow Rate, Supply Temperature and Return Temperature. Output signals shall be either serial network (protocol conforming to BACnet® MS/TP, BACnet/IP, LONWORKS®, JCI-N2, MODBUS RTU RS485, MODBUS RTU TCP/IP, or Siemens-P1) and/or via individual analog and pulse outputs. Each BTU meter shall be factory programmed for its specific application, and shall be re-programmable using the front panel keypad (no special interface device or computer required).
- 3. Temperature sensors: Temperature sensors shall be loop-powered current based (mA) sensors and shall be bath-calibrated and matched (NIST* traceable) for the specific temperature range for each application. The calculated differential temperature used in the energy calculation shall be accurate to within +0.15°F (including the error from individual temperature sensors, sensor matching, input offsets, and calculations).
- 4. Flow Meter: The flow meter shall be installed either in the supply or return pipe of the system to be measured following the manufacturer's instructions with particular attention paid to upstream and downstream straight pipe runs. Insertion type flow meters shall be provided with all installation hardware necessary to enable insertion and removal of the meter without system shutdown and shall be hand insertable up to 400 psi. For installations in non-metallic pipe, install grounding rings or probes as required.

- a. Insertion Electromagnetic Type: Provide an ONICON Model F-3500 Insertion Electromagnetic Flow Meter. Materials of construction for wetted metal components shall be 316 SS. For installations in non-metallic pipe, install grounding rings or probes. The flow meter shall average velocity readings from two sets of diametrically opposed electrodes. Each flow meter shall be individually wet-calibrated against a primary volumetric standard that is accurate to within 0.1% and traceable to NIST*. A certificate of calibration shall be provided with each flow meter. Accuracy shall be within $\pm 1\%$ of rate from 2-20 ft/s. Overall turndown shall exceed 100:1. Output signals shall be completely isolated and shall consist of the following: (1) high resolution frequency output for use with peripheral devices such as an ONICON display module or Btu meter, (1) analog output; 4-20mA, 0-10V, or 0-5V jumper selectable and (1) scalable dry contact output for totalization. Each flow meter shall be covered by the manufacturer's two-year warranty.
- b. Inline (full bore) Electromagnetic Type: Provide an ONICON F-3200 Series Electromagnetic Flow Meter complete with integral or remote electronics module. The electronics module shall include a backlit graphic display and keypad. Connections to the piping shall be ANSI class 150 flanges (ANSI class 300 available where required). The installing contractor is responsible for providing suitable mating flanges. The flow tube shall be epoxy coated steel; the sensing electrodes shall be 316SS; the liner shall be polypropylene or ebonite for low temperature service, PTFE for hot water service. Each flow meter shall be individually wet-calibrated and accurate to within $\pm 0.2\%$ of reading from 1.6 to 33 feet per second velocity. A certificate of calibration shall be provided with each flow meter. Output signals shall be 4-20 mA and programmable pulse. The flow meter shall be capable of measuring bi-directional flow. For installations in non-metallic pipe, install grounding rings between flanges. Each flow meter shall be factory programmed for its specific application, and shall be re-programmable using the integral keypad on the converter (no special interface device or computer required).

C. Commercial Tenant Sub-Metering BTU Meter

1. The entire Energy Measurement System shall be built and calibrated by a single manufacturer, and shall consist of a flow meter, two temperature sensors, a Btu meter, temperature thermowells, and all required mechanical installation hardware. A certificate of NIST* traceable calibration shall be provided with each system. All equipment shall be covered by the manufacturer's two year warranty.
2. Btu Meter: Provide an ONICON System-10 BTU Meter. The Btu meter shall provide the following information via both an integral LCD, and via serial network communications (protocol conforming to BACnet MS/TP, BACnet/IP, LONWORKS®, JCI-N2, MODBUS RTU RS485, MODBUS RTU TCP/IP or Siemens-P1): Energy Total, Energy Rate, Flow Total, Flow Rate, Supply Temperature and Return Temperature. Each Btu meter shall be factory programmed for its specific application, and shall be re-programmable using the front panel keypad (no special interface device or computer required).
3. Flow Meter: Provide an ONICON Turbine Flow Meter. Insertion type flow meters shall be provided complete with all installation hardware necessary to enable insertion and removal of the meter without system shutdown, and be hand-insertable up to 400 psi. Inline meters shall be installed with isolation valves to allow installation or removal of the flow meter without a system shutdown. Turbine rotation shall be detected by electronic impedance-based sensing (non-magnetic). Each flow meter shall be individually wet-calibrated against a primary volumetric standard that is accurate to within 0.1% and traceable to NIST*. A certificate of calibration shall be provided with each flow meter. Accuracy shall be within $\pm 0.5\%$ of rate at the calibrated velocity, within $\pm 1\%$ of rate over a 10:1 turndown (3.0 to 30 ft/s) and within $\pm 2\%$ of rate over a 50:1 turndown (from 0.4 to 20 ft/s). The flow meter shall include an integral 0-15V square wave output as an input to the ONICON Btu Meter.

- a. Model to be selected as follows:
 - 1) Model F-1300 Inline Turbine Flow Meter for line sizes $\frac{3}{4}$ " or 1" (flow rate up to 38 gpm)
 - 2) Model F-1100 Single Turbine Insertion Flow Meter for line sizes 1 $\frac{1}{4}$ " and larger with 30 diameters of straight run pipe available for installation.
 - 3) Model F-1200 Dual Turbine Insertion Flow Meter for line sizes 2 $\frac{1}{2}$ " and larger with less than 30 diameters of straight run pipe available for installation.
4. Temperature sensors: Temperature sensors shall be loop-powered current based (mA) sensors and shall be bath-calibrated and matched (NIST* traceable) for the specific temperature range for each application. The calculated differential temperature used in the energy calculation shall be accurate to within +0.150F (including the error from individual temperature sensors, sensor matching, input offsets, and calculations).

2.2 ELECTRIC POWER METERS

- A. Performance Requirements: Manufacturer shall certify that each energy meter indicated complies with specified performance requirements and characteristics.
 1. Product certificates are required.
- B. Fully Programmable Multifunction Electric Power Meter:
 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Electro Industries.
- C. Power Meter:
 1. Basis of Design:
 - a. Electro Industries Nexus 1500+
 2. The power quality meter shall be UL listed and CE marked.
 3. The power quality meter shall be designed for multifunction electrical measurement on 3 phase power systems:
 - a. The power quality meter shall support 3 element Wye, 2.5 element Wye, 2 element Delta, and 4 wire Delta systems.
 - b. The power quality meter's surge withstand shall conform to IEEE C37.90.1 and ANSI C62.41 (6 kV).
 - c. The power quality meter shall be user programmable for voltage range to any CT or PT ratio.
 - d. The power quality meter shall have a voltage burden of not more than 0.072 VA per phase Max at 600 volts, and 0.003 VA per phase Max at 120 volts.
 - e. The power quality meter shall have a current inputs burden of not more than 0.008 VA per phase max at 20 A.
 - f. The power quality meter shall accept a voltage input range of (5 to 347) V AC Line to Neutral, and a range of (10 to 600) V AC Line to Line.
 - g. The power quality meter shall accept a current reading of up to 20 A continuous. Start-up current for a 5 A input shall be no greater than 0.005 A.
 - h. The power quality meter shall have a frequency range of (42.5 to 69.9) Hz.

4. The power quality meter shall use a dual input method for current inputs. Method one shall allow the CT to pass directly through the meter without any physical termination on the meter, ensuring the meter cannot be a point of failure on the CT circuit. The second method shall provide additional termination pass-through bars that allow the CT leads to be terminated on the meter.
 - a. The Fault Current Withstand shall be 100 A for 10 seconds, 300 A for 3 seconds, and 500 A for 1 second at 23°C.
 - b. The Pass-through wire gauge dimension of 0.177" / 4.5 mm shall be available.
 - c. All inputs to outputs shall be isolated to 2500 V AC.
5. The power quality meter shall measure and report the following quantities at a minimum:
 - a. Watts (total and per phase), VARs (total and per phase), VA (total and per phase), power factor (total and per phase), voltage max/min in the interval, and frequency. The meter shall support high-speed readings updated every cycle, and also programmable high-speed readings updated every 2-20 cycles, simultaneously. Readings shall be available for both metering and control. All specified readings shall be made available through the meter's standard and optional communication ports. An additional set of highest accuracy, one second readings, shall also be available.
 - 1) VA/VAh measurement shall support both arithmetic and vector computation.
 - b. Accumulated watt-hour, VA-hour, and VAR-hour; watt-hour received; watt-hour delivered; VAR-hour and VA-hour readings shall be accumulated and stored for each of the 4 quadrants of power.
 - c. Power demand shall be simultaneously calculated using four different averaging methods: Fixed Window (Block) Average, Sliding Window (Rolling Block) Average, Thermal Average, and Cumulative Demand. Values for all averaging intervals must be available simultaneously.
 - d. Fixed Window (Block) Average interval shall be user-settable from one second to 18 hours. Sliding Window (Rolling Block) Average sub-interval shall be user-settable from one second to 18 hours. The number of intervals in the Sliding Window (Rolling Block) Average shall be user-settable from one to 255 sub-intervals.
6. The power quality meter shall compensate for errors in current transformers and potential transformers.
 - a. Errors shall include voltage, multipoint current, multiphase angle, and better than 0.01% resolution.
 - b. The unit shall utilize five different current compensation points per phase, wherein the points shall be concentrated at the lower end of the dynamic range.
7. The power quality meter shall provide the following accuracies. Accuracies shall be measured as percent of reading at standard meter test points.
 - a. Power meter shall meet ANSI C12.20 for Class 0.2 and IEC 62053-22 Class 0.2S accuracy requirements.
 - b. Voltage accuracy shall be within less than 0.05% for the one second reading and less than 0.1% for 100 millisecond reading.
 - c. Current accuracy shall be within less than 0.025% for the one second reading and less than 0.1% for the 100 millisecond reading.
 - d. Frequency shall have a display resolution accuracy of less than 0.01 Hz for the one second reading and less than 0.03 Hz for the programmable 2-20 cycle readings.
 - e. The meter shall have an internal precision real time clock providing max accuracy at full temperature range to 3.5 ppm, or less than 10 seconds per month drift.

- f. The meter shall offer a Test mode that allows accuracy testing via the meter's front KYZ pulses. Test mode shall offer options (positive or negative watt-hour or positive or negative VAR-hour, per quadrants; test with or without Transformer/Line Loss Compensation and PT/CT Compensation) through software and support preset accumulators upon exiting Test mode.
- 8. The power quality meter shall have calibration components that include:
 - a. Precision internal references with real-time auto calibration for voltage and current channels.
 - b. The ability to self-calibrate at a rate not longer than every ten seconds, for the life of the meter.
 - c. The meter must stabilize its readings once "out of the box" and connected, within 10 seconds.
- 9. The power quality meter shall include upgrade packs that shall enable in-field upgrade without removing the installed meter.
 - a. The three upgrade packs shall be:
 - 1) V1 - Standard power quality meter as described in this document with 512 MegaBytes memory and 512 samples per cycle.
 - 2) V2- V1 plus 1 GigaByte memory and 1024 samples per cycle.
 - 3) V3 - V2 plus 4 GigaBytes memory and 50 MHz Transient recording.
 - 4) V2 and V3 shall enable an IEC 61850 Protocol Network Server for either the standard or optional Ethernet port.
- 10. The power quality meter shall include an integrated 5.7-inch touch screen TFT LCD color display with multiple display modes.
 - a. Display shall support 4 groups of screens: Real Time, Trending, Alarms, and Power Quality modes. Groups of screens shall include:
 - 1) Real Time viewing of voltage, current, power, demand.
 - 2) Accumulated Energy and Time of Use readings.
 - 3) Flicker readings in Instantaneous, Short Term (PST), and Long Term (PLT).
 - 4) Alarm conditions.
 - 5) Phasor analysis.
 - 6) Harmonic spectrum analysis and waveform scopes for both voltage and current.
 - 7) Real Time trending.
 - 8) Log status.
 - 9) Configuration settings.
 - 10) Time of Use.
 - 11) Test Mode.
 - 12) Digital status inputs.
 - b. The Display shall be constructed of bright TFT glass with a high temperature and long-life LED backlight. CCFL backlight shall not be acceptable.
 - c. The meter shall have two LED accuracy test pulses on the meter front
 - d. The display shall support screen rotation to enable vertical meter mounting
 - e. The display shall be selectable for 6 embedded languages - English, Spanish, French, Chinese, Russian, and Portuguese – and shall supply two additional optional language input packs.
- 11. The power quality meter shall provide multiple digital communication ports and support multiple open protocols:

- a. The meter shall include an ANSI Optical port that supports speeds of up to 57,600 bps, for communication to external devices.
- b. The meter shall have one standard 10/100BaseT Ethernet port. With V2 and V3 upgrade packs, this Ethernet port shall offer IEC 61850 protocol in addition to Modbus TCP/IP and DNP 3.0. The IEC 61850 protocol Ethernet network server shall provide the following features:
 - 1) Integrates into any IEC 61850 network.
 - 2) Provides support for Modbus TCP/IP, DNP 3.0, and IEC 61850 protocols simultaneously.
 - 3) Configurable for multiple logical nodes.
 - 4) Provides buffered and unbuffered reporting.
 - 5) Provides configurable.ICD and.CID files.
 - 6) Provides GOOSE messaging.
 - 7) Provides alarms and waveform capture in response to GOOSE messages.
- c. The meter shall have a second Ethernet port. Optional Ethernet port shall be available as either 10/100BaseT or 10/100Base-FX Fiber Optic configuration. With V2 and V3 upgrade packs, the 10/100BaseT Ethernet port shall provide optional IEC 61850 protocol in addition to Modbus TCP/IP. The IEC 61850 protocol Ethernet network server shall provide the following features:
 - 1) Integrates into any IEC 61850 network.
 - 2) Provides support for Modbus TCP/IP, DNP 3.0, and IEC 61850 protocols simultaneously.
 - 3) Configurable for multiple logical nodes.
 - 4) Provides buffered and unbuffered reporting.
 - 5) Provides configurable.ICD and.CID files.
 - 6) Provides GOOSE messaging.
 - 7) Provides alarms and waveform capture in response to GOOSE messages.
- d. The standard and optional Ethernet ports shall be separately configurable to enable or disable each port's protocol and service, independently, for the following functions:
 - 1) DNP LAN/WAN over Ethernet.
 - 2) Modbus TCP/IP server.
 - 3) Modbus TCP/IP client.
 - 4) HTTP Web access.
 - 5) SMTP email client for alarm notification.
 - 6) SNTP time synchronization.
 - 7) FTP server support.
 - 8) IEC 61850 protocol server (only one port at a time can be enabled for IEC 61850).
 - 9) SNMP protocol.
 - 10) Separate port numbers can be assigned for every network service.
- e. The meter shall have two optional RS485 ports through the Dual Pulse Output/RS485 card. The card shall have 4 user-programmable KYZ pulse outputs. Each RS485 port shall be user configurable with regard to speed, protocol, address, and other communications parameters. All ports shall support a communication speed of up to 115200 baud simultaneously, and be assignable for Modbus or DNP 3.0 communication.
- f. The meter shall have a high-speed USB port mounted on the front panel.
- g. The meter shall communicate simultaneously using Modbus RTU, Modbus ASCII, DNP 3.0, Modbus TCP/IP, DNP over Ethernet, SNMP protocol, and with V2 and V3 upgrade packs, IEC 61850 protocols as standard configurations. All instantaneous data, logged data, event data, power quality analysis and waveform information shall be available using both Modbus

- TCP/IP and FTP file transfer format. The meter shall also provide means for custom Modbus mapping.
- h. The meter shall include DNP 3.0 protocol utilizing a level 2 implementation, for communication to SCADA systems. All instantaneous data and average data shall be available using DNP 3.0 protocol. User shall be able to custom map data into DNP protocol using Communicator EXT™ software.
12. The meter shall have input/output expandability through four Option card slots on the meter's back and through optional external input/output modules.
- a. The Option cards shall be capable of being installed in the field, without removing the meter from installation.
 - b. The meter shall auto-detect the presence of any Option cards.
 - c. The available Option cards shall be:
 - 1) Dual RS485/Pulse Output card.
 - 2) Ethernet card with RJ45 or Fiber Optic port with 100BaseT support.
 - 3) Up to two Relay Output cards with 6 output relays on each card
 - 4) Up to two Digital Input Status cards with 16 inputs on each card.
 - d. The meter shall have optional external input/output modules in the following configurations:
 - 1) The meter shall support up to 4 Analog Output Modules in 0-1 mA or 4-20 mA, in either 4 or 8 analog output models.
 - 2) The meter shall support up to one Digital Dry Contact Relay Output Module, with 4 relay outputs.
 - 3) The meter shall support up to 4 Digital Solid State Pulse Output modules for KYZ pulsing.
 - 4) The meter shall support up to 4 Analog Input Modules for external sensing of temperature or process conditions.
 - a) In total the meter must be able to support 13 external I/O modules.
 - 5) External input/output modules shall be powered by external power source and attached to the meter with mounting brackets. Mounting brackets shall come equipped with DIN Rail mounting clips.
13. The power quality meter's Ethernet port(s) shall act as a Web server.
- a. Web server shall host webpages with meter information. Multiple meters may be displayed on the webpages. Webpages shall be viewable using any standard Internet browser. Webpages shall provide access to live meter readings, power quality information, and general meter information, and also shall enable remote upgrades to the meter's firmware.
 - b. Web server shall operate without ActiveX controls or Java Applets and shall be readable via smart phone and/or tablet computing devices.
 - c. Web server shall operate through firewalls.
 - d. Web server shall support emailing of alarm conditions to configured email addresses.
 - e. Web server shall be fully customizable.
 - f. The meter shall support DNP over Ethernet and at least 32 simultaneous sockets Modbus TCP/IP per each Ethernet card, standard and optional.
14. The power quality meter shall internally record and store Time of Use data.
- a. The following Time of Use parameters must be included:

- 1) Bi-directional consumption and demand.
 - 2) Configurable month and season accumulators.
 - 3) Up to 4 seasons and 12 months available.
 - 4) Perpetual TOU profile that only needs to be set up once and can be used for unlimited number of years.
 - b. The meter must provide the following TOU information for all rates in real time.
 - 1) Current month accumulations
 - 2) Previous month accumulations
 - 3) Current season (or weekly, or daily) accumulations
 - 4) Previous season (or weekly, or daily) accumulations
 - 5) Total accumulations to date
 - 6) Cumulative demand
 - c. Full four quadrant accumulations for watt-hr, VAR-hr, VA-hr and coincident VARs during peak watt demand including max demand, shall be available for each rate schedule, each season and for total accumulations.
 - d. Continuous cumulative demand shall be available.
15. The power quality meter shall have eight built-in digital high-speed status inputs:
 - a. Inputs shall automatically sense when the circuit is externally wetted.
 - b. If externally wetted, inputs shall accept up to 150 VDC; if internally wetted the meter shall supply the necessary voltage for the control application.
 - c. Status inputs shall be configurable for pulse accumulation, pulse synchronization, or event monitoring. When used for pulse accumulation, each input shall have an accumulating register to count incoming pulses.
 - d. All changes in status shall be time stamped to the nearest millisecond and placed in an event log with time and event label information.
 - e. Event log shall enable users to recreate sequence of events involving external status points.
 - f. High-speed status inputs shall be able to trigger waveform recording to the waveform log.
 - g. Inputs shall record at 1 cycle RMS, and also be programmable for 2-20 cycles RMS recording.
16. The power quality meter shall enable users to perform Flicker analysis and reporting and shall comply fully with the requirements of IEC 61000-4-15 and IEC 61000-4-30 Class A Edition 3.
 - a. The meter shall provide logging and monitoring for Instantaneous, Short Term readings (PST-10min) and Long Term readings (PLT-4 hour).
 - b. Flicker shall support both 220 volt/50 Hz systems and 120 volt/60 Hz systems.
 - c. The meter shall offer full reporting of power quality conditions using the IEC 61000-4-30 Class A methodology. The meter shall support automatic generation of EN 50160/IEC 61000-4-30 reports at user-settable intervals. Reports shall be viewable with a Log Viewer program and downloadable to other applications. In support of IEC 61000-4-30 Class A methodology, the meter shall calculate group and sub-group values for harmonics and interharmonics, up to the 51st order. Thresholds for the harmonic and interharmonic values shall be programmable. The sub-group readings and over-threshold status shall be available through the Flicker log and Modbus registers.
 - d. The meter shall offer programmable thresholds for all of the IEC 61000-4-30 reporting values so the user can customize their EN 50160 report as needed.
17. The power quality meter shall have 16-bit Waveform and Fault Recorder.

- a. The meter shall record up to 1024 samples per cycle continuously on all 8 channels simultaneously, and transient captures sensitive to at least 800,000 samples per cycle. Storage for recorded waveform samples shall be up to 4000 MegaBytes.
 - b. The meter shall perform voltage and current recording with pre and post-event analysis when a waveform limit is exceeded. Pre and post-events shall be configurable to up to 179 cycles.
 - c. Fault recording shall offer 8 times full scale capture capability.
 - d. The meter shall allow viewing of voltage and current Harmonic magnitudes to the 127th order. The meter's Harmonic measurement shall fully comply with the IEC 61000-4-7 standard.
 - e. Percent THD and K-factor shall be calculated by the meter.
 - f. The accuracy of the IRIG-B time stamping of the waveform capture shall be 100 microseconds.
18. The power quality meter with upgrade pack V3 shall have a sub-cycle Transient recorder.
- a. The transient recorder shall process 50 MHz high-speed voltage transients.
 - b. Transients will be analyzed utilizing a field programmable gate array (FPGA) to designate the high peak transient magnitude and its duration in nanoseconds.
19. The power quality meter shall be equipped with extensive non-volatile memory for recording logs and programming data.
- a. The meter shall be equipped with at least 4000 MegaBytes of non-volatile storage.
 - b. In the event of loss of control power, the data stored in memory shall be retained for no less than ten years.
 - c. The meter shall have no less than eight historical logs. Each historical log shall be user configurable, and the user can allot the amount of memory for each log. The user must be able to select up to 128 parameters per log.
 - d. The meter shall have a log for limits/alarms. The Limits log shall provide magnitude and duration of an event, its time-stamp, and log value.
 - e. The meter shall have a log for System Events. The System Events log shall record the following occurrences with a time-stamp: demand resets, password requests, security information (e.g., sealing switch activation, network password change), system startup, energy resets, log resets, log downloads, Firmware updates, V-Switch™ key upgrades, Test Mode activity, meter time changes, clock compensation activity, changes to IEC 61850 SCL file, TOU Profile update, change in meter's serial number, updates to meter boards or display, and programmable settings changes.
 - f. The meter shall have a log for High-speed Input status changes.
 - g. The meter with upgrade pack V3 shall have a log which is capable of recording a waveform, both when a user-programmed value goes out of limit and when the value returns to within limit.
 - h. The meter shall store a separate ITIC/CBEMA log that records magnitude and duration of voltage and current surges and sags for every power quality event. The CBEMA log shall be downloadable through the digital communication ports.
20. The power quality meter shall provide a separate IRIG-B input for time synchronizing to a GPS time signal.
- a. IRIG-B input shall accept un-modulated time signal input from a standard GPS satellite clock.
 - b. Time input shall enable synchronizing of meter time to within one millisecond of Universal Standard Time as transmitted by the GPS clock system. Synchronizing shall not be subject to network or other delays.
21. The power quality meter shall be programmable by software supplied by the meter manufacturer.

- a. Software shall have a user-friendly, Windows® OS compatible interface.
 - b. Software shall include capacity to program meter, download meter, and analyze downloaded data files.
 - c. Software shall store all data in an ODBC compliant database. Data based storage shall include all log and waveform data.
22. The power quality meter shall provide limits/alarms and control capability as follows:
- a. Limits shall be configurable for any measured parameter.
 - b. Up to 32 limits shall be configurable.
 - c. Limits shall be based on % of Full Scale settings.
 - d. Manual Relay control shall be available through software.
 - e. Relay set delays and reset delays shall be available.
 - f. The meter shall allow alarms and waveform recording based on IEC 61850 protocol GOOSE messages.
23. The power quality meter shall be able to act as a Master RTU device.
- a. The meter shall have the ability to poll remote Modbus slave devices, read data from the slave devices, and log the data for RTU concentrator functions.
 - b. The meter's Master RTU port shall support Modbus RTU.
24. The power quality meter shall have password and sealing switch protection.
- a. The meter shall support a bi-level and extended password configuration.
 - 1) Level 1 shall provide access to TOU accumulations.
 - 2) Level 2 shall provide access to all password protected functions.
 - 3) Level 2 shall allow the creation of up to 8 additional password profiles with specific restrictions and capabilities.
 - b. The meter shall support a sealing switch consisting of a physical lock located on the bottom left section of the meter front, and a software setting to enable/disable the sealing switch. When it is enabled, the sealing switch shall further restrict access to password protected features, such as demand resetting.
25. The meter's SNMP protocol shall be available for either or both the standard Ethernet port and the optional Ethernet port. The meter's SNMP implementation shall:
- a. Support SNMP protocol V1 and V2c.
 - b. Support over 60 measurements.
 - c. Include traps for limits, input change, and power quality.
 - d. Support Cold Start trap and Authentication Failure.
26. The power quality meter shall be appropriately constructed to provide long life in abusive physical and electrical environments.
- a. Meter firmware shall be held in flash RAM and shall be upgradeable through one of the communications ports, without removing the unit from service.
 - b. The meter shall operate successfully at temperature extremes of -20°C to +70°C.
 - c. Depending on ordered option, the meter shall operate with control power from either (100-240) V AC or (90-265) V AC@50/60 Hz ; (100-370) V DC; or (18-60) V DC.
 - d. The meter shall have a standard 4-year warranty.
27. The power quality meter shall be Electro Industries/GaugeTech model: Nexus® 1500+ meter. No substitution allowed.

D. Tenant Sub-Meters:

1. Basis of Design:
 - a. Electro Industries MP200
2. The Unit shall be UL listed and CE marked.
3. The Unit shall consist of either of two circuit configurations: 8 multifunction electrical measuring points (meters) for 3 phase power systems or 24 multifunction electrical measuring points (meters) for single phase power systems. The Unit's meters shall perform to spec in harsh electrical applications in high and low voltage power systems.
 - a. The Unit shall support 3 element Wye, single phase 3-wire and 2-wire systems, and 2 CT Delta.
 - b. The Unit's surge withstand shall conform to IEEE C37.90.1.
 - c. The Unit shall be user programmable for voltage range to any PT ratio.
 - d. The Unit shall accept a burden of up to .09 VA per phase, Max at 600 volts, and 0.014 VA at 120 volts.
 - e. The Unit shall accept a voltage input range of up to 576 volts Line to Neutral, and up to 721 volts Line to Line with a universal voltage system input.
 - f. The meters shall accept a current reading of up to 20 A continuous.
 - g. The Unit/meters shall have color-coordinated voltage and current inputs.
4. The Unit's meters shall have an accuracy of +/- 0.5% or better for voltage and current, and 0.5% for power and energy functions. The Unit shall meet the accuracy requirements of IE C62053-22 (Class 0.5%) and ANSI C12.20 (Class 0.5%).
 - a. The meters shall provide true RMS measurements of voltage, phase to neutral and phase to phase; current, per phase (for the three phase meter circuit configuration) and neutral.
 - b. The Unit shall provide sampling at 400+ samples per cycle on each measured channel simultaneously, at 24-bit resolution.
5. The Unit shall have data-logging memory of up to 32 MB. With data-logging, the Unit shall support:
 - a. One fully configurable and one pre-configured Historical log (for trending Energy use over time).
 - b. An Alarm/Limits log that records the state of the 16 limits that can be programmed for the meter
 - c. A System Events log to store events that happen in, or to the meter, including Startup, Reset commands, Log retrievals, and attempts to log on with a password.
 - d. An I/O Change log to record changes in the inputs and outputs of the Relay Output/Status Input board.
6. The Unit's meters shall be traceable revenue meters. The Unit which shall contain at least 8 utility grade test pulses allowing power providers to verify and confirm that the meters are performing to their rated accuracy.
7. The Unit shall offer the following communication ports:
 - a. Com 1 shall support RS485 and optional RJ45 Ethernet/802.11b WiFi. It shall support Modbus RTU, Modbus ASCII, and Modbus TCP; and baud rates from 9,600 to 57,600.
 - b. Com 2 shall be a USB Serial port. It shall support Modbus ASCII and a baud rate of 57,600.
 - c. Com 3 shall support RS485. It shall support Modbus RTU and Modbus ASCII; and baud rates from 9,600 to 57,600.
8. The Unit shall have a Relay Output/Status Input board:

- a. The board shall have 2 Relay Outputs for control applications. The relay outputs shall be able to be triggered by the user-programmed limits in the meters. The user shall be able to assign up to 16 limits, including below-and above-limit conditions for any value the meter measures.
 - b. The board shall have 4 KYZ Counting Inputs. The KYZ inputs shall be able to be configured to count pulses from gas, water, condensate, and other commodity measuring devices.
9. The Unit shall provide user configured block window or rolling window demand so the user can set up the particular utility demand profile:
 - a. Readings for kW, kVAR, kVA and PF shall be calculated using utility demand features. All other parameters shall offer max and min capability over the user selectable averaging period.
 - b. Voltage shall provide an instantaneous max and min reading displaying the highest surge and lowest sag seen by the meter.
10. The Unit shall be upgradeable after installation. Upgrade packs accessed through the optional Com port shall allow the base model (V1) to be upgraded to support basic load profiling with 2MB of Memory (V2) and upgraded to support advanced load profiling with 32MB of memory (V3).
11. The Unit shall consist of an all-metal enclosure and shall have the following physical properties:
 - a. The Unit shall measure 7.6(L) x 11.28(W) x 4.36(H) in. / 19.3(L) x 28.65(W) x 11.07(H) cm.
 - b. The Unit shall be able to be mounted within an electrical panel.
 - c. The Unit shall have a stud-base connection for current inputs.
12. The Unit shall have an optional display for remote or local reading.
 - a. The display shall be available in 5.7".
 - b. The display shall be a touch-screen LCD display, rated for indoor use.
 - c. The display shall support over 65k colors.
 - d. The display shall support RS485 serial and RJ45 Ethernet communication, simultaneously.
 - e. The display shall auto-detect the type of communication being used.
 - f. The display shall be pre-configured to display readings for both the 8 three phase meters and the 24 single phase meters circuit configurations.
 - g. The display shall provide the names of each circuit being metered.
 - h. The display shall also provide important diagnostic data like meter date and time, a graphical phasor diagram, and out of limit conditions.
 - i. The display shall be capable of displaying non-electrical parameters like water, gas, and steam usage.
 - j. The unit shall have the capability of utilizing both a local and remote display, simultaneously.
13. The Unit shall have a 4-year warranty.
14. Acceptable product is Electro Industries/GaugeTech, Model: MP200-Y-60-10-V1-X or MP200-S-60-10-V1-X.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.

3.3 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.13

SECTION 230923.14 - FLOW INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Airflow measurement stations and sensors.
 - 2. Liquid flow meters.
 - 3. Liquid flow transmitters.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.14.

1.3 DEFINITIONS

- A. Ethernet: Local area network based on IEEE 802.3 standards.
- B. FEP: Fluorinated ethylene propylene.
- C. HART: Highway addressable remote transducer protocol is the global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring systems through bi-directional communication that provides data access between intelligent field instruments and host systems. A host can be any software application from technician's hand-held device or laptop to a plant's process control, asset management, safety, or other system using any control platform.
- D. PEEK: Polyetheretherketone.
- E. PTFE: Polytetrafluoroethylene.
- F. PPS: Polyphenylene sulfide.
- G. RS-485: A TIA standard for multipoint communications using two twisted pairs.
- H. RTD: Resistance temperature detector.
- I. TCP/IP: Transport control protocol/Internet protocol incorporated into Microsoft Windows.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics; electrical characteristics; and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 3. Product description with complete technical data, performance curves, and product specification sheets.
 - 4. Installation instructions, including factors affecting performance.
 - 5. Product certificates.
- B. Sustainable Design Submittals:
 - 1. Product data showing compliance with ASHRAE 62.1.
- C. Shop Drawings:
 - 1. Include plans, elevations, sections, and mounting details.
 - 2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.
 - 4. Include diagrams for air and process signal tubing.
 - 5. Number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.5 INFORMATIONAL SUBMITTALS

- A. Product Certificates: For each product requiring a certificate.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For instruments to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 GENERAL REQUIREMENTS FOR FLOW INSTRUMENTS

- A. Air sensors and transmitters shall have an extended range of 10 percent above Project design flow and 10 percent below minimum Project flow to signal abnormal flow conditions and to provide flexibility for changes in operation.

- B. Liquid and steam sensors, meters, and transmitters shall have an extended range of 10 percent above Project design flow and 10 percent below Project minimum flow to signal abnormal flow conditions and to provide flexibility for changes in operation.
- C. Source Limitations: For flow instruments, obtain products from single source from single manufacturer.

2.3 AIRFLOW MEASUREMENT STATIONS AND SENSORS

A. Performance Requirements:

- 1. Adjustable for changes in system operational parameters.
- 2. Airflow Sensor and Transmitter Range: Extended range of 10 percent above Project design flow and 10 percent below minimum Project flow to signal abnormal flow conditions.
- 3. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.
 - a. Product certificates are required.

B. Thermal Airflow Measurement Stations:

1. Common Performance Requirements:

- a. Provide stations that are adjustable for changes in system operational parameters.
- b. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.
- c. Thermal airflow stations with one or more sensor nodes mounted in a probe, and a remotely mounted microprocessor-based transmitter at each measurement location.
- d. Sensor Nodes: One self-heated and one zero-power bead-in-glass thermistor, using the principle of thermal dispersion.
- e. Airflow Rate and Temperature of Each Sensor: Equally weighted and averaged by the transmitter prior to output.
- f. Sensor-Node and Probe Assemblies:
 - 1) Sensor-Node Construction: Two bead-in-glass, hermetically sealed thermistors potted in a marine-grade waterproof epoxy with sensor housings constructed of glass-filled polypropylene. Construct with only the thermistor located within the sensing node and all other electronic components outside the airstream. Epoxy- or glass-encapsulated chip thermistors or devices with exposed leads are not allowed. Devices that use epoxy- or glass-encapsulated chip thermistors, or electronics in the airstream, are unacceptable. Devices with exposed leads are unacceptable.
 - 2) Store sensor-node airflow and temperature calibration data in a serial memory chip, in the cable connecting plug. Stored data does not require matching or adjustments to the transmitter in the field.
 - 3) Sensing-Node Temperature Accuracy: Within 0.15 deg F over an operating range of minus 20 to plus 160 deg F and humidity range of 0 to 100 percent RH.
 - 4) Sensor-Probe Mounting Bracket Construction: Type 304 stainless steel.
 - 5) Internal Probe Wiring: Kynar-coated copper between the connecting cable and sensor nodes. PVC-jacketed wiring is unacceptable.
 - 6) Internal Probe Wiring Connections: Solder joints and spot welds, sealed and protected from the elements, so that direct exposure to water will not affect instrument operation. Connectors within the probe, of any type, are unacceptable. Printed circuit boards within the probe are unacceptable.

- 7) Sensor-Probe Jacket: Integral, FEP jacket, plenum-rated CMP/CL2P, UL/cUL-listed cable, rated for exposures from minus 67 to plus 392 deg F , and for continuous and direct UV exposure. Plenum-rated PVC jacket cables are unacceptable.
- 8) Sensor-Probe Cable Connector Plug: Gold-plated pins for connection to the transmitter.
- g. Transmitter Features and Functions:
 - 1) High and/or low airflow alarm with user-defined set point and percent of set-point tolerance.
 - 2) Manual or automatic alarm reset, and low-limit cutoff value may be selected to disable the alarm.
 - 3) Alarm delay function, field defined.
 - 4) Sensor-node malfunction via the system status alarm and ignore the sensor node that is in a fault condition.
 - 5) Field configuration, diagnostics, and field output adjustment wizard that allow for a one- or two-point field adjustment to factory calibration for installations that require adjustment.
 - 6) Automatic reset after power disruption, transients, and brown-outs through a watchdog timer circuit.
 - 7) Operating temperature range of minus 20 to plus 120 deg F and humidity range of 5 to 95 percent RH.
 - 8) Electrical Power Requirement: 24 V ac (between 22.8 and 26.4 V ac under load) at 20 VA maximum, using a switching power supply that is overcurrent and overvoltage protected.
 - 9) Printed Circuit Board Interconnects: Gold-plated edge fingers, receptacle plug pins, and printed circuit board test points.
 - 10) Printed Circuit Boards: Electroless nickel immersion gold (ENIG) plated.
 - 11) Integrated Circuitry: Temperature-rated, industrial-grade. Commercial-grade integrated circuitry is not acceptable.
 - 12) Integration Buffers: Separate integration buffers for display of airflow output, airflow signal output (analog and network), and individual sensor output (IR-interface).
2. For Air-Ducted/Plenum:
 - a. Airflow Station Performance:
 - 1) Independent processing of up to 16 separately wired sensor-node assemblies.
 - 2) Accuracy: Within 3 percent of reading for ducted applications, and within 5 percent of reading for non-ducted applications, when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - b. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory results.

- 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 5000 fpm.
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Provide the number of independent sensor nodes as follows:
 - a) For Duct/Plenum Area up to 0.5 sq. ft. : One.
 - b) For Duct/Plenum Area Greater Than 0.5 through 1.0 sq. ft. : Two.
 - c) For Duct/Plenum Area Greater Than 2.0 through 4.0 sq. ft. : Six.
 - d) For Duct/Plenum Area Greater Than 4.0 through 8.0 sq. ft. : Eight.
 - e) For Duct/Plenum Area Greater Than 8.0 through 12.0 sq. ft. : 12.
 - f) For Duct/Plenum Area Greater Than 12.0 through 14.0 sq. ft. : 14.
 - g) For Duct/Plenum Area Greater Than 14.0 sq. ft. : 16.
 - 4) For an aspect ratio of 1.5 or less, and an area of 25 sq. ft. or greater, four probes are required.
 - 5) Sensor-Probe Construction: Gold-anodized, 6063 aluminum alloy tube or Type 316 stainless steel tube, with each sensor probe containing one or more independently wired sensing nodes.
- c. Transmitter:
- 1) Transmitter determines the average airflow rate and temperature of connected sensor nodes in an array for a single location.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC116 Transmitter: Two field-selectable 0-to 10-V dc, or 4- to 20-mA, scalable, isolated, overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - b) Model GTM116 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, and overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node

temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.

- c) Model GTL116 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
- d) Model GTD116 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.

3. For Air-Ducted/Plenum - Duct Size 2 sq. ft. or Less:

a. Airflow Station Performance:

- 1) Independent processing of up to four separately wired sensor-node assemblies.
- 2) Accuracy: Within 3 percent of reading for ducted applications, and within 5 percent of reading for non-ducted applications, when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.

b. Sensor-Node and Probe Assemblies:

- 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
- 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 5000 fpm.
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
- 3) Provide the number of independent sensor nodes as follows:
 - a) For Duct/Plenum Area up to 0.5 sq. ft. : One.
 - b) For Duct/Plenum Area Greater Than 0.5 through 1.0 sq. ft. : Two.
 - c) For Duct/Plenum Area Greater Than 1.0 sq. ft. : Four.
- 4) For probes less than 8 inches
- 5) Sensor-Probe Construction: Gold-anodized, 6063 aluminum alloy tube or Type 316 stainless steel tube, with each sensor probe containing one or more independently wired sensing nodes.

c. Transmitter:

- 1) Transmitter determines the average airflow rate and temperature of connected sensor nodes in an array for a single location.

- 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals or one isolated RS-485 (BACnet MS/TP, or Modbus RTU) field-selectable network connection.
 - 3) Model HTA104 Transmitter, Analog Capability: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, and overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm.
 - 4) Model HTAN104 Transmitter, Network Communications: The RS-485 (BACnet MS/TP or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures.
4. For Supply or Return Fan Array:
- a. Airflow Station Performance:
 - 1) Independent processing of up to eight separately wired sensor-node assemblies.
 - 2) Accuracy: Within 10 percent of reading under operating conditions, when installed in accordance with manufacturer's sensor density and placement guidelines, with no effect on fan performance. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - b. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
 - 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 10,000 fpm(0 to 50.8 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Sensor-Probe Construction: One sensor node mounted on a Type 304 stainless steel block with two adjustable zinc-plated steel rods connected to Type 304 stainless steel pivoting mounting feet.
 - 4) Number of Independent Sensor Nodes, Fan Arrays (One to Eight Fans): One probe with one sensor node per probe in each fan inlet.
 - c. Transmitter:
 - 1) Transmitter determines the average airflow rate and temperature of each fan. Startup firmware facilitates the setup of multiple fans and fan areas.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC108 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field

configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.

- b) Model GTM108 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, and overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - c) Model GTL108 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
 - d) Model GTD108 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.
5. For Supply or Return Fan, Single-Width Single-Inlet (SWSI) or Double-Width Double-Inlet (DWDI) Fans - Both Analog and Network Outputs:
- a. Airflow Station Performance:
 - 1) Independent processing of up to eight separately wired sensor-node assemblies.
 - 2) Accuracy: Within 10 percent of reading under operating conditions, when installed in accordance with manufacturer's sensor density and placement guidelines, with no effect on fan performance. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - b. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.

- 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 10,000 fpm(0 to 50.8 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Sensor-Probe Construction: One sensor node mounted on a Type 304 stainless steel block with two adjustable zinc-plated steel rods connected to Type 304 stainless steel pivoting mounting feet.
 - 4) Number of Independent Sensor Nodes, SWSI Fans, and DWDI Fans: Two probes with one sensor node per probe in each fan inlet.
- c. Transmitter:
- 1) Transmitter determines the average airflow rate and temperature of each fan. Startup firmware facilitates the setup of multiple fans and fan areas.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC108 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - b) Model GTM108 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, and overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.

- c) Model GTL108 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
 - d) Model GTD108 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.
- 6. For Supply or Return Fan, Single-Width Single-Inlet (SWSI) or Double-Width Double-Inlet (DWDI) Fans - Either Analog or Network Outputs:
 - a. Airflow Station Performance:
 - 1) Independent processing of up to four separately wired sensor-node assemblies.
 - 2) Accuracy: Within 10 percent of reading under operating conditions, when installed in accordance with manufacturer's sensor density and placement guidelines, with no effect on fan performance. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - b. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
 - 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 10,000 fpm(0 to 50.8 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - c. Sensor-Probe Construction: One sensor node mounted on a Type 304 stainless steel block with two adjustable zinc-plated steel rods connected to Type 304 stainless steel pivoting mounting feet.
 - d. Number of Independent Sensor Nodes, SWSI Fans, and DWDI Fans: Two probes with one sensor node per probe in each fan inlet.
 - e. Transmitter:
 - 1) Transmitter determines the average airflow rate and temperature of connected sensor nodes in an array for a single location.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals or one isolated RS-485 (BACnet MS/TP or Modbus RTU) field-selectable network connection.
 - 3) Model HTA104 Transmitter, Analog Capability: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, and overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm.
 - 4) Model HTN104 Transmitter, Network Communications: The RS-485 (BACnet MS/TP or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures.

7. For Air Terminal Units:
8. Airflow Station Performance:
 - a. Independent processing of up to two separately wired sensor-node assemblies.
 - b. Accuracy: Within 3 percent of reading when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
9. Sensor-Node and Probe Assemblies:
 - a. Sensor-Node Calibration:
 - 1) Individually calibrated at a minimum of seven calibration points to NIST-traceable volumetric standards from 0 to 3000 fpm(0 to 15.2 m/s).
 - 2) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - b. Provide the number of independent sensor nodes as follows:
 - 1) For a Duct Diameter of 4 Inches(102 mm): One.
 - 2) For Duct Diameters 5 through 16 Inches(127 through 406 mm): Two.
 - c. Sensor-Probe Construction: Mill-finish, 6063 aluminum alloy tube or Type 316 stainless steel tube, with each sensor probe containing one or more independently wired sensing nodes.
10. Transmitter:
 - a. Transmitter determines the average airflow rate and temperature of all connected sensor nodes in an array for a single location.
 - b. User Interface: An alpha-numeric, LCD display, with two field-selectable analog output signals or one isolated RS-485 (BACnet MS/TP or Modbus RTU) field-selectable network connection.
 - c. Model EF-A Transmitter, Analog Capability: Two field-selectable 1- to 5-V dc, 0- to 10-V dc, or 2- to 10-V dc, scalable analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm.
 - d. Model EF-N Transmitter, Network Communications: The RS-485 (BACnet MS/TP or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures.
 - e. Contact Closure Relay: One dry contact relay with onboard jumper to drive a remote LED, rated for no less than 30 V dc or 24 V ac at 3 A maximum. User configurable as normally open or normally closed during set up.
11. For Packaged HVAC Units, 12.5 Tons(44.0 kW) or Smaller:
 - a. Airflow Station Performance:
 - 1) Independent processing of up to two separately wired sensor-node assemblies.
 - 2) Accuracy: Within 10 percent of reading when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy

is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.

b. Sensor-Node and Probe Assemblies:

- 1) Sensor-Node Internal Wiring Connections: Sealed and protected from the elements and suitable for direct exposure to water. Devices with exposed leads are unacceptable.
- 2) Sensor-Node Calibration:
 - a) Individually calibrated at a minimum of seven calibration points to NIST-traceable airflow standards from 0 to 3000fpm (0 to 15.2 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
- 3) Provide the number of independent sensor nodes as follows:
 - a) For a Duct Diameter of 4 Inches(102 mm): One.
 - b) For Duct Diameters 5 through 16 Inches(127 through 406 mm): Two.
- 4) Sensor-Probe Construction: Mill-finish, 6063 aluminum alloy tube, with each sensor probe containing one or more independently wired sensing nodes.

c. Transmitter:

- 1) Transmitter determines the average airflow rate and temperature of all connected sensor nodes in an array for a single location.
- 2) User Interface: An alpha-numeric, LCD display, with two field-selectable analog output signals or one isolated RS-485 (BACnet MS/TP or Modbus RTU) field-selectable network connection.
- 3) Model EF-A Transmitter, Analog Capability: Two field-selectable 0- to 10-V dc, or 2- to 10-V dc, scalable analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm.
- 4) Model EF-N Transmitter, Network Communications: RS-485 (BACnet MS/TP or Modbus RTU) network connection to provide average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures.
- 5) Contact Closure Relay: One dry contact relay with onboard jumper to drive a remote LED, rated for no less than 30 V dc or 24 V ac at 3 A maximum. User configurable as normally open or normally closed during set up.

12. For Directional Airflow:

- a. Bi-directional airflow measurement station with temperature output and integral airflow alarming to determine the exfiltration or infiltration airflow rate, and its direction and temperature at each measurement location.
- b. Bi-directional airflow, or equivalent differential pressure data, is provided to the BAS, with system status indication, configurable airflow alarm, and internal diagnostics routine.
- c. Sensor-Node Calibration:
 - 1) Individually calibrated at a minimum of nine calibration points to NIST-traceable volumetric standards from minus 3000 to plus 3000 fpm(minus 15.2 to plus 15.2 m/s).

- 2) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Probe to Transmitter Cables: Integral, FEP jacket, plenum-rated CMP/CL2P, UL/cUL-listed cable, rated for exposures from minus 67 to plus 392 deg F(minus 55 to plus 200 deg C), and UV tolerant, with terminal plug for connection to the remotely mounted transmitter.
 - d. Transmitter:
 - 1) Transmitter determines the average airflow rate and temperature of all connected sensor nodes in an array for a single location.
 - 2) User Interface: An alpha-numeric, LCD display, with two field-selectable analog output signals or one isolated RS-485 (BACnet MS/TP or Modbus RTU) field-selectable network connection.
 - 3) Model EF-A Transmitter, Analog Capability: Two field-selectable 0- to 10-V dc, or 2- to 10-V dc, scalable and protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature low and/or high airflow set-point alarm (user-defined) or system status alarm.
 - 4) Model EF-N Transmitter, Network Communications: The RS-485 (BACnet MS/TP or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures.
 - 5) Contact Closure Relay: One dry contact relay with onboard jumper to drive a remote LED, rated for no less than 30 V dc or 24 V ac at 3 A maximum. User configurable as normally open or normally closed during set up.
13. For Data Center Server Rack Airflow/Pressure and Temperature Monitor:
 - a. Manufacturers: Subject to compliance with requirements:
 - 1) Ebtron, Inc.
 - b. Bi-directional airflow measurement station with temperature output and integral airflow alarming to determine the exfiltration or infiltration airflow rate, and its direction and temperature at each measurement location.
 - c. Bi-directional airflow, or equivalent differential pressure data, is provided to the BAS, with system status indication, configurable airflow alarm, and internal diagnostics routines.
 - d. Sensor-Node and Probe Assemblies:
 - 1) Sensor-Node Internal Wiring Connections: Sealed and protected from the elements and suitable for direct exposure to water. Devices with exposed leads are unacceptable.
 - 2) Sensor Node Calibration:
 - a) Individually calibrated at a minimum of nine calibration points to NIST-traceable volumetric standards from minus 2000 to plus 2000 fpm(minus 10.2 to plus 10.2 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - e. Probe to Transmitter Cables: Integral, FEP jacket, plenum-rated CMP/CL2P, UL/cUL-listed cable, rated for exposures from minus 67 to plus 392 deg F(minus 55 to plus 200 deg C), and UV tolerant, with terminal plug for connection to the remotely mounted transmitter. Plenum-rated PVC jacket cables are unacceptable.

- f. Transmitter:
 - 1) Integral Transmitter with Display: Mounted internally to the rack enclosure an integral, minimum 16-character LCD display capable of simultaneously displaying airflow and temperature, and capable of displaying individual airflow and temperature readings.
 - 2) Transmitter Interface: Four-button interface for field configuration and diagnostics.
 - 3) Power Supply: On-off power switch, 110 V ac at 8 VA, fused and protected from overvoltage, overcurrent, and power surges. Provide dual independent and redundant power supplies.
 - 4) Network Interface: One isolated Ethernet network connection (simultaneously supporting field-selectable BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP protocols).
- 14. For Combination Control Damper and Airflow Station - Equal Area Method Distribution Pattern:
 - a. Manufacturers: Subject to compliance with requirements:
 - 1) Ebtron, Inc.
 - b. Thermal airflow station and integral damper with two or more sensor nodes mounted in a probe, and a remotely mounted microprocessor-based transmitter at each measurement location. Sensor-node distribution pattern to be based on equal area method.
 - c. Airflow Station Performance:
 - 1) Independent processing of up to 16 separately wired sensor-node assemblies.
 - 2) Accuracy: Within 3 percent of reading for ducted applications, and within 5 percent of reading for non-ducted applications, when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
 - d. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
 - 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 5000 fpm (0 to 25.4 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Provide the number of independent sensor nodes as follows:
 - a) For Damper Area up to 1.0 sq. ft. (0.092 sq. m): Two.
 - b) For Duct/Plenum Area Greater Than 1.0 through 4.0 sq. ft. (0.092 through 0.372 sq. m): Four.
 - c) For Duct/Plenum Area Greater Than 4.0 through 8.0 sq. ft. (0.372 through 0.743 sq. m): Six.

- d) For Duct/Plenum Area Greater Than 8.0 through 12.0 sq. ft. (0.743 through 1.11 sq. m): Eight.
 - e) For Duct/Plenum Area Greater Than 12.0 through 16.0 sq. ft. (1.11 through 1.49 sq. m): 12.
 - f) For Duct/Plenum Area Greater Than 16.0 sq. ft. (1.49 sq. m): 16.
- 4) Sensor Probe Construction: Gold-anodized, 6063 aluminum alloy tube with each sensor probe containing one or more independently wired sensing nodes.
- e. Transmitter:
- 1) Transmitter determines the average airflow rate and temperature of connected sensor nodes in an array for a single location.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC116 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - 3) Model GTM116 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, and overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - 4) Model GTL116 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
 - 5) Model GTD116 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.

- f. Integral Control Damper and Sleeve:
 - 1) Frame and Sleeve: Extruded 6063T5 aluminum with an integral damper frame.
 - a) Thickness: Not less than 0.080-inch thickness for each damper section.
 - b) Sleeve Depth: 15 inches(381 mm) for ducted applications and 18 inches(457 mm) for non-ducted applications including damper frame. Non-ducted applications include a 3-inch-(7.6-mm-) radius, aluminum entry flair.
 - c) Installation: Provide an additional 7 inches(178 mm) for non-ducted, 10 inches(254 mm) for ducted, applications between the downstream edge of an intake louver and the leading edge of the entry flair for outside air intake applications that are close coupled to intake louvers.
 - d) Leakage: The damper leakage shall not exceed 3 cfm/sq. ft.(15.2 L/s per sq. m) of face area against 1-inch wg(248.8-Pa) differential static pressure.
 - 2) Blades: Extruded 6063T5 aluminum airfoil blades not less than 0.060-inch(1.52-mm) thickness.
 - a) Blade Seals: Extruded EPDM.
 - b) Frame Seals: Extruded silicone secured in an integral slot within the aluminum extrusions.
 - c) Orientation: Parallel or opposed blade configuration as required by application.
 - 3) Bearings: Celcon inner bearing fixed to a 7/16-inch(11.1-mm) aluminum hexagon blade pin, rotating within a polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact.
 - 4) Linkage: Aluminum- and corrosion-resistant zinc-plated steel, complete with cup-point trunnion screws for a slip-proof grip, installed inside the frame.
 - 5) Control-Damper Actuator: Modulating, electronic, damper actuator of sufficient number and adequate size, factory mounted and tested. Control-damper actuators are specified in Section 230923.12 "Control Dampers."
- 15. For Combination Control Damper and Airflow Station - Modified Log Distribution Pattern:
 - a. Manufacturers: Subject to compliance with requirements:
 - 1) Ebtron, Inc.
 - b. Thermal airflow station and integral damper with one or more sensor nodes mounted in a probe, and a remotely mounted microprocessor-based transmitter at each measurement location. Sensor node distribution pattern to be based on modified log Tchebycheff method.
 - c. Airflow Station Performance:
 - 1) Independent processing of up to 16 separately wired sensor-node assemblies.
 - 2) Accuracy: Within 3 percent of reading for ducted applications, and within 5 percent of reading for non-ducted applications, when installed in accordance with manufacturer's recommended placement guidelines. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.

- d. Sensor-Node and Probe Assemblies:
- 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
 - 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 5000 fpm(0 to 25.4 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Provide the number of independent sensor nodes as follows:
 - a) For Damper Area up to 1.0 sq. ft.(0.092 sq. m): Two.
 - b) For Duct/Plenum Area Greater Than 1.0 through 2.0 sq. ft.(0.092 through 0.185 sq. m): Four.
 - c) For Duct/Plenum Area Greater Than 2.0 through 4.0 sq. ft.(0.185 through 0.372 sq. m): Six.
 - d) For Duct/Plenum Area Greater Than 4.0 through 8.0 sq. ft.(0.372 through 0.743 sq. m): Eight.
 - e) For Duct/Plenum Area Greater Than 8.0 through 12.0 sq. ft.(0.743 through 1.11 sq. m): 12.
 - f) For Duct/Plenum Area Greater Than 12.0 through 14.0 sq. ft.(1.11 through 1.30 sq. m): 14.
 - g) For Duct/Plenum Area Greater Than 14.0 sq. ft.(1.49 sq. m): 16.
 - 4) Sensor Probe Construction: Gold-anodized, 6063 aluminum alloy tube with each sensor probe containing one or more independently wired sensing nodes.
- e. Transmitter:
- 1) Transmitter determines the average airflow rate and temperature of connected sensor nodes in an array for a single location.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC116 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.

- b) Model GTM116 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, and overcurrent protected analog output signals and network output capability. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - c) Model GTL116 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
 - d) Model GTD116 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.
- f. Integral Control Damper and Sleeve:
- 1) Frame and Sleeve: Extruded 6063T5 aluminum with an integral damper frame.
 - a) Thickness: Not less than 0.080-inch(2.0-mm) thickness for each damper section.
 - b) Sleeve Depth: 13 inches(330 mm) for all applications including damper frame. Sleeve includes a 1-inch-(2.56-mm-) radius, aluminum entry flair.
 - c) Installation: Provide an additional 7 inches(178 mm) between the downstream edge of an intake louver and the leading edge of the entry flair for outside air intake applications that are close coupled to intake louvers.
 - d) Leakage: The damper leakage shall not exceed 3 cfm/sq. ft.(15.2 L/s per sq. m) of face area against 1-inch wg(248.8-Pa) differential static pressure.
 - 2) Blades: Extruded 6063T5 aluminum airfoil blades not less than 0.060-inch(1.52-mm) thickness.
 - a) Blade Seals: Extruded EPDM.
 - b) Frame Seals: Extruded silicone secured in an integral slot within the aluminum extrusions.
 - c) Orientation: Parallel or opposed blade configuration as required by application.
 - 3) Bearings: Celcon inner bearing fixed to a 7/16-inch(11.1-mm) aluminum hexagon blade pin, rotating within a polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact.
 - 4) Linkage: Aluminum- and corrosion-resistant zinc-plated steel, complete with cup-point trunnion screws for a slip-proof grip, installed inside the frame.
 - 5) Control-Damper Actuator: Modulating, electronic, damper actuator of sufficient number and adequate size, factory mounted and tested. Control-damper actuators are specified in Section 230923.12 "Control Dampers."

16. For Combination Backdraft Damper and Airflow Station:

- a. Manufacturers: Subject to compliance with requirements:
 - 1) Ebtron, Inc.
- b. Thermal airflow station with one or more sensor nodes mounted in a probe, and a remotely mounted microprocessor-based transmitter at each measurement location.
- c. Airflow Station Performance:
 - 1) Independent processing of up to eight separately wired sensor-node assemblies.
 - 2) Accuracy: Within 10 percent of reading under operating conditions, when installed in accordance with manufacturer's sensor density and placement guidelines, with no effect on fan performance. Include the combined uncertainty of the sensor nodes and transmitter. For devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter, demonstrate compliance with the accuracy requirement over the entire operating range.
- d. Sensor-Node and Probe Assemblies:
 - 1) Performance rated and tested with a 100 percent survival rate in a 30-day saltwater and acid vapor test with written independent laboratory test results.
 - 2) Sensor-Node Calibration: Individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard.
 - a) Accuracy: Within 2 percent of reading over the entire calibrated airflow range of 0 to 10,000 fpm(0 to 50.8 m/s).
 - b) Individually calibrate thermistor at a minimum of three temperatures to NIST-traceable temperature standards.
 - 3) Sensor-Probe Construction: One sensor node mounted on a Type 304 stainless steel block with two adjustable zinc-plated steel rods connected to Type 304 stainless steel pivoting mounting feet.
 - 4) Number of Independent Sensor Nodes, Fan Arrays (One to Eight Fans): One probe with one sensor node per probe in each fan inlet.
- e. Transmitter:
 - 1) Transmitter determines the average airflow rate and temperature of each fan. Startup firmware facilitates the setup of multiple fans and fan areas.
 - 2) User Interface: 16-character, alpha-numeric, LCD display, with two field-selectable analog output signals and network output capability. Provide one of the following transmitter configurations:
 - a) Model GTC108 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The RS-485 (BACnet MS/TP, or Modbus RTU) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and

temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.

- b) Model GTM108 Transmitter: Two field-selectable 0- to 10-V dc, or 4- to 20-mA, scalable, isolated, and overcurrent protected analog output signals. The first output (AO1) provides the total airflow rate. The second output (AO2) is field configurable for temperature or low and/or high airflow set-point (user-defined) or system status alarm. The Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection provides the average airflow rate, temperature, high and/or low airflow set-point alarm, system status alarm, individual sensor-node airflow rates, and individual sensor-node temperatures. The transmitter shall be provided with a Bluetooth low-energy interface card capable of transmitting all transmitter setup parameters, diagnostics, average airflow, and temperature of the device and the airflow and temperature of each sensor node. Software capable of capturing and displaying this transmission will be available via download to Android or iOS phone or tablet. Software shall allow for setup parameters, airflow, temperature, and diagnostic data to be saved on the phone or be emailed.
 - c) Model GTL108 Transmitter with LonWorks Free Topology Network Interface: Connection capable of providing average airflow and temperature rates across the network.
 - d) Model GTD108 Transmitter with Data-Logger Interface: Capable of logging airflow and temperature rates over specified time intervals.
- f. Integral Heavy-Duty Backdraft Damper:
- 1) Frame and Sleeve: Extruded 6063T5 aluminum with an integral damper frame.
 - a) Thickness and Depth: Not less than 0.080-inch(2.0-mm) thickness.
 - b) Sleeve Depth: 8 inches, which act as an integrated sleeve. Optional 1-inch-(7.6-mm-) radius, aluminum entry flair.
 - c) Installation: Provide an additional 7 inches(178 mm) between the downstream edge of any components and leading edge of the damper frame or entry flare.
 - d) Leakage: The damper leakage shall not exceed 3 cfm/sq. ft.(15.2 L/s per sq. m) of face area against 1-inch wg(248.8-Pa) differential static pressure.
 - 2) Blades: Extruded 6063T5 aluminum airfoil blades not less than 0.060-inch(1.52-mm) thickness.
 - a) Blade Seals: Extruded EPDM.
 - b) Frame Seals: Extruded silicone secured in an integral slot within the aluminum extrusions.
 - c) Orientation: Parallel configuration as required by application.
 - 3) Bearings: Celcon inner bearing fixed to a 7/16-inch(11.1-mm) aluminum hexagon blade pin, rotating within a polycarbonate outer bearing inserted in the frame, resulting in no metal-to-metal or metal-to-plastic contact.
 - 4) Linkage: Aluminum- and corrosion-resistant zinc-plated steel, complete with cup-point trunnion screws for a slip-proof grip, installed inside the frame.

C. Pitot-Tube Airflow Sensor Station:

1. Manufacturers: Subject to compliance with requirements:
 - a. Air Monitor Corporation.
2. Description: Multiple total- and static-pressure sensors positioned at the center of equal area of the station cross section and interconnected by respective averaging manifolds.
 - a. Stations 4 sq. ft. and Smaller: One total-pressure sensor and one static-pressure sensor for every 16 sq. in. of station area.
 - b. Stations Larger than 4 sq. ft. : One total-pressure sensor and one static-pressure sensor for every 36 sq. in. of station area.
3. Casing: Galvanized sheet steel at least 0.079 inch thick with coating complying with ASTM A 653/A 653M, G90. Casings shall be stainless steel, 0.0781 inch thick, when connected to stainless duct and aluminum, 0.063 inch thick, when connected to aluminum duct.
 - a. Joints and Seams: Continuously weld. Clean galvanized areas damaged by welding and coat with aluminum paint.
 - b. Casing Depth: At least 8 inches.
 - c. Casing Flanges: Outward flange, minimum flange face 1.5 inches.
 - d. Casing Configuration and Size: Match shape (rectangular, round, flat oval) and same size as adjacent duct unless otherwise indicated.
4. Include an open parallel cell air straightener or air equalizer honeycomb mechanically fastened to casing.
 - a. Construct straightener or equalizer from Type 3003 aluminum or Type 316 stainless steel, depending on casing material. Use stainless steel for units with stainless-steel casings.
5. Construct pressure sensor array from drawn copper or stainless-steel tubing. Use stainless steel for units with stainless-steel casings. Copper tubing shall comply with ASTM B 75 and ASTM B 280. Minimum tube wall thickness shall be 0.030 inch. Include internal piping and external pressure transmitter ports.
6. Station Labeling: Identification label on each station casing indicating model number, size, area, and application-specific airflow range.
7. Performance:
 - a. Pressure Loss: 0.015-inch wg at 1000 fpm , or 0.085-inch wg at 2000 fpm.
 - b. Accuracy: Within 2 percent of actual airflow.
 - c. Self-Generated Sound: NC 40 and sound level within the duct shall not be amplified.
 - d. Performance rated and tested according to AMCA 610. Each station shall bear the AMCA seal.

D. Pitot-Tube Fan Inlet Airflow Traverse Sensor:

1. Manufacturers: Subject to compliance with requirements:
 - a. Air Monitor Corporation.
2. Traverse manifold designed for mounting in fan inlets.
3. Contain multiple total- and static-pressure sensors placed at concentric area centers along the exterior surface of cylindrical manifold and internally connected to their respective averaging

- manifolds. Sensors shall not protrude beyond the surface of the manifold nor be adversely affected by particle contamination present in airstream.
4. Manifold (two per inlet) shall have dual end support swivel brackets suitable for mounting in the fan inlet bell and symmetrical averaging signal takeoffs and fittings.
 5. Sensors shall be capable of producing steady, non-pulsating signals of standard total- and static-pressure without need for flow corrections or factors, with an accuracy of 3 percent of actual flow over a turndown range of 6 to 1.
 6. Manifold Materials: Copper or anodized aluminum or Type 316 stainless steel.
 7. Unless otherwise required by application and without affecting the fan and sensor performance, nominal diameter copper and aluminum manifolds shall be the following:
 - a. For Fan Inlets Smaller Than 20 Inches : 0.375 inch.
 - b. For Fan Inlets 20 Inches and Larger: 0.75 inch.
 8. Unless otherwise required by application and without affecting the fan and sensor performance, nominal diameter stainless steel manifolds shall be the following:
 - a. For Fan Inlets Smaller Than 20 Inches : 0.375 inch.
 - b. For Fan Inlets 20 through 48 Inches : 0.75 inch.
 - c. For Fan Inlets Larger Than 48 Inches : 1.0 inch.
- E. Piezometer Ring Fan Inlet Airflow Sensor:
1. Manufacturers: Subject to compliance with requirements:
 - a. Twin City Fan & Blower.
 2. In lieu of externally mounted fan inlet airflow sensors, option to provide fans with airflow measurement integral to fan inlet cones for continuous measurement of air volume flow rate.
 3. Multiple pressure sensor points strategically placed along the circumference of the inlet cone and internally connected to an averaging ring manifold located behind the inlet cone.
 4. Sensor points shall not protrude beyond the surface of the inlet cone nor be adversely affected by particle contamination present in the airstream.
 5. Sensor shall produce steady, non-pulsating signals to achieve accuracy within 5 percent of actual airflow.
 6. Sensor shall be non-intrusive and not impact fan performance.
 7. Product shall be a standard offering of the fan manufacturer and include published literature with supporting test data to validate sensor performance.

2.4 LIQUID FLOW METERS

A. General Requirements for Liquid Flow Meters:

1. Adjustable for changes in system operational parameters.
2. Liquid and Steam Sensors, Meters, and Transmitters: Extended range of 10 percent above Project design flow and 10 percent below Project minimum flow to signal abnormal flow conditions.
3. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.
4. Product certificates are required.

B. Insertion Paddle Wheel Flow Meter, NPS 2 :

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Badger Meter, Inc.
 - b. Veris Industries.
2. Description: Insertion-type meter with a non-magnetic spinning paddle wheel.
3. Turbine, insertion type, with isolation valve and packing gland for removal under full line pressure. Wetted parts shall be corrosion resistant. Range shall be from 3 fps to 30 fps with water as the medium. Accuracy shall be $\pm 3\%$ at any operating point. The flow meter signal conditioner shall output a 4-20 mA signal and shall provide zero and span adjustments. The conditioner enclosure shall be NEMA 4.
4. Performance:
 - a. Range: 0.5 to 30 fps.
 - b. Accuracy: Within 1 percent of full scale overflow range.
 - c. Linearity: Within 0.2 percent of full scale overflow range.
 - d. Repeatability: Within 0.3 percent of full scale overflow range.
 - e. Ambient Temperature: 14 to 150 deg F.
 - f. Maximum Process Temperature: 221 deg F.
 - g. Maximum Pressure: 400 psig at 100 deg F.
5. Output Signal: Frequency pulse.
6. Construction:
 - a. Wetted Metal Parts, Including Sensor Sleeve, Mounting Adapter, and Isolation Valve: Type 316 stainless steel.
 - b. Shaft: Type 316 stainless steel.
 - c. Impeller: Tefzel.
 - d. Process Connection: NPS 2.
 - e. Instrument Isolation Valve: Gate valve for system isolation.
 - f. Insertion Depth: Threaded positioning nut for accurate sensor depth in the pipe.
 - g. Electronics Enclosure:
 - 1) Polyphenylene sulfide (PPS) with Viton seal.
 - 2) Electrical Connection: Cable furnished with sensor.
7. Transmitter:
 - a. User-adjustable scale to refine resolution of flow range over 4- to 20-mA signal.
 - b. Enclosure Material: Polycarbonate with tongue and groove, with neoprene sealed cover.
 - c. NEMA 250, Type 4X enclosure.
 - d. Electrical Connection: Screw terminals.
 - e. Linearity less than one percent.
 - f. Output Response Time: 6 seconds for 10 to 90 percent step.
 - g. Load resistance of 650 ohms at 24-V dc.
 - h. Operating Temperature: Minus 32 to plus 122 deg F.
 - i. Digital display of flow rate.

C. Insertion Paddle Wheel Flow Meter, NPS 1 :

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Badger Meter, Inc.
2. Description:

- a. Insertion-type meter with a non-magnetic spinning paddle wheel.
 - b. Each meter shall be wet calibrated at factory to standards traceable to NIST and provided with a certificate of calibration.
 - c. Programming kit including cable connector and Microsoft-Windows-compatible software.
 - d. Where indicated, provide meter with bi-directional flow measurement.
3. Performance:
 - a. Range: 0.33 to 20 fps.
 - b. Accuracy: Within 0.5 percent of flow rate.
 - c. Repeatability: Within 0.5 percent.
 - d. Ambient Temperature: 14 to 150 deg F.
 - e. Maximum Process Temperature: 300 deg F with PEEK sensor tip.
 - f. Maximum Pressure: 350 psig at 300 deg F with PEEK sensor tip.
 - g. Pressure Drop: Up to 0.5 psig at 10 fps for pipe sizes NPS 1-1/2 and larger.
4. Output Signal:
 - a. Unidirectional Flow Meter: Frequency pulse.
 - b. Unidirectional Flow Meter: Analog, two wire, loop-powered, 4- to 20-mA signal.
 - c. Unidirectional Flow Meter: Scaled pulse.
 - d. Bi-directional Flow Meter: Analog 4- to 20-mA signal plus direction.
 - e. Bi-directional Flow Meter: Scaled pulse.
5. Operator Interface:
 - a. Programming: Instrument programming through computer and programming kit.
 - b. Digital Display: Eight-character digital display of flow rate, flow totalization, input, output, and flow direction for bi-directional meters.
6. Construction:
 - a. Wetted Metal Parts (Including Sensor Stem, Mounting Adapter, and Isolation Valve): Type 316 stainless steel.
 - b. Sensor Tip: PPS or PEEK.
 - c. Shaft: Tungsten carbide.
 - d. Impeller: Stainless steel.
 - e. Process Connection: NPS 1.
 - f. Instrument Isolation Valve: Full port ball valve for system isolation.
 - g. Insertion Depth: Threaded positioning nut for accurate sensor depth in the pipe.
 - h. Electronics Enclosure:
 - 1) Polypropylene with Viton-sealed acrylic cover.
 - 2) Removable cover.
 - 3) NEMA 250, Type 4X.
 - 4) Electrical Connection: Screw terminals.
 - 5) Conduit Connection: 1/2-inch trade size.

D. Insertion Turbine Flow Meter:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. ONICON Incorporated.
2. Description:
 - a. Operating pressure of 300 psig with a temperature of 200 deg F.
 - b. Meters in hot water systems shall be suitable for maximum system temperatures encountered, but not less than 250 deg F.

- c. Pressure drop not to exceed 1 psig at 20-fps flow velocity in a NPS 2 pipe and decreasing in large pipe with lower velocity.
 - d. Sensor Accuracy:
 - 1) Within 1 percent of actual flow between the flow velocity range of 3 to 30 fps.
 - 2) Within 2 percent of actual flow between the flow velocity range of 0.4 to 20 fps.
 - 3) Within 0.5 percent of actual reading at the calibrated velocity.
 - e. Wet calibrate and tag sensors to standards traceable to NIST, and provide each sensor with a certificate of calibration.
3. Sensor:
- a. For Pipe Sizes NPS 2 and Smaller: Single turbine sensors.
 - b. For Pipe Sizes NPS 2-1/2 and Larger: Dual turbine sensors.
 - c. Piping with Bi-directional Flow: Bi-directional dual turbine sensors.
 - d. Dual turbine sensors shall have dual, contra-rotating turbine elements, each turbine element with its own rotational sensing system, and an averaging circuit.
 - e. Rotational sensing of each turbine shall be accomplished electronically by sensing electronic impedance change (non-magnetic and non-photoelectric).
 - f. Sensor shall have an integral frequency output linear with flow rate. For dual turbine units, with individual top and bottom turbine outputs for diagnostic purposes.
 - g. Bi-directional sensors shall have isolated solid-state dry contacts with a contact rating of 100 mA at 50 V. The contacts shall close when the flow in direction of arrow is 0.18 fps or more.
 - h. Flow sensor shall be complete with installation hardware necessary to enable insertion and removal from pipe without system shutdown.
 - i. Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts. Construct wetted metal components of Type 316 stainless steel, including installation hardware.
 - j. House sensor electronics in a NEMA 250, Type 4 enclosure.
 - k. Enclosure shall include connection(s) for field-installed conduit.
 - l. Sensor shall have cable of length sufficient to connect to display module.
 - m. Sensor housing shall have full port Type 316 stainless steel ball valve for system isolation.
4. Display Module:
- a. Remote from sensor.
 - b. House in a NEMA 250, Type 4X enclosure.
 - c. Label terminal strip for all wiring connections.
 - d. 120-V ac power supply with 24-V dc output to power the flow sensor.
 - e. Remote Interface:
 - 1) Hardwired Analog Outputs for Flow Rate and Totalization: 4 to 20 mA and zero- to 10-V dc.
 - 2) Serial Communication Interface: Compatible with host to share flow rate and totalized flow data.
 - 3) Outputs linear to within 0.1 percent of calibrated span.
 - f. Digital display for flow rate and totalized flow.
 - 1) At least eight display digits for totalization.
 - 2) Bi-directional units with separate digital display for flow and totalization in each direction.
 - g. Local reset of flow totalization.
 - h. Program and data shall be stored in nonvolatile memory in event of power loss.
 - i. For bi-directional units, with display of flow direction (contacts open or closed).

E. Insertion Electromagnetic Flow Meter

- 1. Basis of Design ONICON F-3500/FB3500 Insertion Electromagnetic meter or pre-approved equal.

2. Applications:
 - a. Chilled/Hot Water, Condenser Water and Water/Glycol Solutions for HVAC
 - b. Condenser Water/Irrigation Water
 - c. Domestic Water/Municipal Water/Well Water
 - d. Process Water and Water mixtures
3. Description:
 - a. Sensor shall have no moving parts and be a magnetic flow sensor, which utilizes Faraday's Law to measure fluid flow through a pipe. The flow meter shall consist of 2 elements, the sensor and the electronics. The sensor/electronics, (flow meter) shall generate a signal proportional to the flow velocity thru the pipe.
 - b. Suitable for flow measurement of fluids with electrical conductivity between 20 to 60000 micro-Seimens per centimeter.
 - c. Suitable for pipe sizes NPS 1.25" through NPS 138 (DN 32 through DN 1800).
 - d. Wet calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.
 - e. Meter complete with all installation hardware necessary to enable insertion and removal of the meter without system shutdown.
4. Sensor shall have:
 - a. Wetted Metal Parts: Type 316 stainless steel
 - b. Sensor Head: Xarec
 - c. Electrodes: Type 316 stainless steel.
 - d. Flow Range: 0.1 to 20 fps (0.1 to 6.0 m/s).
 - e. Process Temperature: 15 to 250 deg. F (Minus 9 to plus 121 deg. C).
 - f. Pressure: 400 psig (2758 k/Pa).
 - g. Dual direction, sensor flow in positive or negative value (Optional)
5. Transmitter shall have:
 - a. Transmitter integral to the meter
 - b. Electronics Enclosure:
 - 1) Painted aluminum, NEMA 250, Type 4.
 - 2) Removable cover.
 - 3) Electrical Connection: PVC-jacketed cable, 10 feet (3 m) long.
 - 4) Conduit Connection: 1/2-inch ((16 mm)) trade size.
 - 5) Power: 20-28 Vac/Vdc
 - c. Ambient Temperature: Minus 20 to 150 deg. F (Minus 29 to plus 66 deg. C).
 - d. Output Signals:
 - 1) Field-selectable analog signals.
 - a) Current Signal (Isolated): 4 to 20 mA.
 - b) Voltage Signal (Isolated): Zero- to 5 or 10-Vdc.
 - 2) Digital Signal: Dry-contact closure signaling fault condition.
 - 3) Frequency Signal: Zero- to 15-V peak pulse, zero to 500 Hz.
 - 4) Scalable Pulse Output:
 - a) Isolated solid-state dry contact.
 - b) Contact Rating: 100 mA at 50-V dc.
 - c) Pulse Duration: 0.5, 1, 2, or 6 seconds.
 - 5) Directional Contact Output: <Optional>
 - a) Isolated solid-state dry contact

- b) Switch closed when flow is in the direction of the arrow on enclosure at 0.2 ft/sec
- 6. Accuracy:
 - a. ± 1 percent of reading for flow velocities between 2 and 20 fps (0.61 to 6.0 m/s)
 - b. ± 0.02 ft/sec for flow velocities below 2 fps (0.61 m/s)
- 7. Warranty:
 - a. The flow meter shall be covered by the manufacturer's three-year warranty.
- 8. Installation:
 - a. Install per manufactures installation instruction.
 - b. Dedicated earth ground required
 - c. Flow measurement with minimum for 10 pipe diameters upstream of a single elbow and five pipe diameters downstream
- 9. Display Module:
 - a. Provide ONICON Model D-1200 Series Display Module
 - b. 24V power
 - c. Remote from sensor/transmitter
 - d. House in a Painted Steel NEMA 4 enclosure.
 - e. Labeled terminal strip for all wiring connections.
 - f. Power from the display to power the flow meter.
 - g. Input Signal from Meter: Zero- to 15-V pulse
 - h. Digital display for flow rate and totalized flow.
 - i. Bi-directional units, provide LED display of flow direction (contacts open or closed). (Optional)
- 10. BAS Interface:
 - a. Provide ONICON Model D-100 Series BAS Interface
 - b. 24V power
 - c. Power from the display to power the flow meter.
 - d. House in a NEMA. 13
 - e. Serial Communication Interface: Compatible with host to share flow rate and totalized flow data. N2 Modbus RTU Modbus TCP/IP BACnet MSTP BACnet IP Analog outputs
 - f. Digital display for flow rate and totalized flow.
 - g. At least eight display digits for totalization.
 - h. Local reset of flow totalization.
 - i. Program and data shall be stored in nonvolatile memory in event of power loss.
- F. Ultrasonic Clamp-on Flow Meter
 - 1. Products subject to compliance with requirements, American Made, Buy America Act FAR 52.225.1, and field serviceable.
 - a. Basis-of-Design Product: ONICON; F-4300 Clamp-on Ultrasonic Flow meter
 - 2. Description:
 - a. Provide a clamp-on transit time ultrasonic flowmeter complete with a processor / transmitter, non-wetted matched transducers, self-aligning installation hardware and triaxial transducer cables and calibration certificate and installations and operating instructions.
 - b. The contractor shall be responsible for selecting the flowmeter options submitted based on the application. Flowmeter shall be constructed, calibrated and scaled for the intended application in terms of pipe size, pipe material, installation requirements, expected flow rate,

- ambient conditions and fluid characteristics which include but are not limited to pressure, temperature and viscosity
- c. The meter shall display flow rate and flow total with an integral display and support field programming of all parameters. The meter shall also have integral diagnostics to verify installation conditions and the proper operation of the meter.
 - d. Each flow meter shall be individually calibrated against a N.I.S.T. traceable standard and receive a certificate of calibration. Each flow meter shall be factory programmed based on the application data specified at time of order.
 - e. The meter shall provide 128-megabyte data logger for baseline monitoring
 - f. Each meter shall be factory programmed using project-specific application data.
 - g. Flow-measuring element and transmitter shall cover operating range of equipment or system served.
3. Sensors/Transducers:
 - a. Ultrasonic transit time velocity-measurement utilizing non-wetted transducers matched for the specific applications in terms of pipe size and pipe material
 - b. Operating range: 40° F to 250° F
 - c. Pipe size range: 2.00" to 24"
 - d. Installation Hardware: Self-aligning painted aluminum, 316 SS clamping bands and Coaxial cable capable of mounting transducer from display.
 4. Transmitter/Display:
 - a. Provide an operator interface consisting of five push-buttons. Display shall visually indicate instantaneous flow rate and total fluid volume. Electrical enclosure shall be clear weather tight, NEMA 4X polycarbonate.
 - b. Operating Power: 18 to 30 Vdc/Vac or
 - c. Outputs signals:
 - 1) Current: Isolated 4-20 mA/0-5Vdc, 1000 Ω max impedance, liner to flow field selectable.
 - 2) Pulse output: (2) programmable optically isolated dry contacts, Rated at 30 Vdc/10mA maximum, Duration 50ms
 - 3) Programmable for flow direction, scaled pulse or alarms.
 - 4) RS485 Modbus RTU or BACnet MS/TP
 - 5) Alphanumeric 5-digit floating decimal for flow rate, 14-digit totalizer, pulse and operating status display, and programming display
 - 6) Integral auto-zero function shall be provided.
 - 7) Program and data shall be stored in nonvolatile memory in the event of power loss
 5. Accuracy:
 - a. Flowmeter shall provide calibrated outputs directly from the transmitter, throughout the operating range with the accuracy stated as follows:
 - 1) ± 1.0 percent of reading from 1 to 20 ft./sec
 - 2) ± 0.01 ft./sec for velocities < 1ft/sec
 6. Warranty:
 - a. The flow meter shall be covered by the manufacturer's three-year warranty
 7. Installation:
 - a. Install per manufacturer's installation instruction.
 - b. See installation detail on mechanical drawing details.
 8. BAS Interface:
 - a. Provide ONICON Model D-100 Series BAS Interface
 - b. 24V Power
 - c. Power from the display to power the flow meter.

- d. House in a NEMA. 13 Enclosure
- e. Serial Communication Interface: Compatible with host to share flow rate and totalized flow data. N2 Modbus RTU BACnet MSTP Analog outputs
- f. Digital display for flow rate and totalized flow.
- g. Eight display digits for totalization.
- h. Local reset of flow totalization
- i. Program and data shall be stored in nonvolatile memory in event of power loss.

G. Ultrasonic Inline Flow Meter:

1. Products subject to compliance with specifications, Products: Subject to compliance with Requirements of, American Made, Buy America Act FAR 52.225.1, ASHREA 62, FCC Part 15 Subpart B, CE, AWWA:C750-10, ANSI/NSF 61 and 37.2, and field serviceable
 - a. Basis of design: ONICON; F-4600 Inline Ultrasonic Flow meter
2. Applications:
 - a. Domestic/Municipal water
 - b. Chilled/Hot Water, Condenser Water and Water/Glycol Solutions for HVAC
 - c. Steam Condensate
 - d. Process Applications for Water Flow
3. Description:
 - a. Sensor shall be a differential transit time flow meter, which measures the difference of the transit times of ultrasonic sound waves traveling between two, wetted direct beam ultrasonic, transducers to determine flow velocity and direction of fluid flow through a pipe
 - b. Each meter shall be factory NIST calibrated. The manufacturer shall provide a certificate of calibration for meter.
 - c. Each meter shall be programmed using project-specific application data.
 - d. Meter shall include integral diagnostics to verify installation conditions and proper operation.
4. Sensors/Transducers
 - a. Material: Lead Free brass
 - b. Pipe size range: 0.50" to 2.5"
 - c. Pressure: 400 Psig
 - d. Temperature Range: 32° F to 250° F
 - e. Flow Measurement Range: 0.03 to 12.86 Ft/Sec
 - f. Pressure drop < 1.5 PSI at design flow
5. Transmitter/Display shall include
 - a. Electrical enclosure shall be weather tight polycarbonate, NEMA 4
 - b. Enclosed terminal block, cable access through standard 3/4" conduit opening.
 - c. Operating Temperature: 13 to 131 ° F.
 - d. Operating Humidity: 5 to 95% Non-Condensing
 - e. Power: 24 VC/DC 50/60 Hz.
 - f. Outputs signals
 - 1) Current: (Non-Isolated)4-20 mA, (Externally Powered)
 - 2) Pulse output: Isolated Solid State, 50mA at 30 VDC, Duration 1 second
 - 3) BACnet MSTP or Modbus RTU
 - g. Backlit alphanumeric 2-line, 16 Character per line, multifunctional LCD display, 0.2" Character height.
 - h. The meter shall display flow rate, flow totalization, and support field programming of all parameters.
 - i. Program and data shall be stored in nonvolatile memory in the event of power loss.
6. Accuracy:

- a. $\pm 1\%$ at Velocities – 0.8 to 12.8 ft/sec.
 - b. $\pm 2\%$ at Velocities – 0.2 to 12.8 ft/sec.
 - c. Repeatable = $\pm 0.2\%$
7. Warranty:
- a. The flow meter shall be covered by the manufacturer's three-year warranty
8. Installation:
- a. Flow meters shall be Install per manufactures installation instruction.
 - b. See installation detail on mechanical drawing details.
9. BAS Interface:
- a. Provide ONICON Model D-100 Series BAS Interface
 - b. Power from the display to power the flow meter.
 - c. d. House in a NEMA 13 enclosure.
 - d. Serial Communication Interface: Compatible with host to share flow rate and totalized flow data. N2 Modbus RTU Modbus TCP/IP BACnet MSTP BACnet IP Analog outputs
 - e. Digital display for flow rate and totalized flow.
 - f. At least eight display digits for totalization.
 - g. Local reset of flow totalization
 - h. Program and data shall be stored in nonvolatile memory in event of power loss.

H. Inline Turbine Flow Meter:

1. Manufacturers: Subject to compliance with requirements, undefined:
- a. ONICON Incorporated.
2. Description:
- a. Available in NPS 3/4 and NPS 1.
 - b. Operating pressure of 300 psig with a temperature of 200 deg F.
 - c. Meters in hot water systems shall be suitable for maximum system temperatures encountered, but not less than 250 deg F.
 - d. Pressure drop not to exceed 3 psig at 38 gpm.
 - e. Sensor Accuracy:
 - 1) Within 2 percent of actual flow between the flow range of 0.8 to 38 gpm.
 - 2) Within 0.5 percent of actual reading at the calibrated velocity.
 - f. Wet calibrate and tag sensors to standards traceable to NIST, and provide each sensor with a certificate of calibration.
3. Sensor:
- a. Rotational sensing of turbine shall be accomplished electronically by sensing electronic impedance change (non-magnetic and non-photoelectric).
 - b. Sensor shall have an integral frequency output linear with flow rate.
 - c. Sensor shall have threaded union on each end.
 - d. Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts.
 - e. Construct wetted metal components of brass or stainless steel.
 - f. House sensor electronics in a NEMA 250, Type 4 enclosure.
 - g. Enclosure shall include connection(s) for field-installed conduit.
 - h. Sensor shall have cable of length sufficient to connect to display module.
4. Display Module:
- a. Remote from sensor.

- b. Enclosure: NEMA 250, Type 4X.
 - c. Label terminal strip for all wiring connections.
 - d. 120-V ac power supply with 24-V dc output to power the flow sensor.
 - e. Remote Interface:
 - 1) Hardwired Analog Outputs for Flow Rate and Totalization: 4 to 20 mA and zero- to 10-V dc.
 - 2) Serial Communication Interface: Compatible with host to share flow rate and totalized flow data.
 - 3) Outputs linear to within 0.1 percent of calibrated span.
 - f. Digital display of flow rate and totalized flow.
 - g. At least eight display digits for totalization.
 - h. Local reset of flow totalization.
 - i. Program and data shall be stored in nonvolatile memory in the event of power loss.
- I. In-line Body Electromagnetic Flow Meter:
- 1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. ONICON Incorporated.
 - 2. Description:
 - a. No moving parts.
 - b. Suitable for flow measurement of fluids with electrical conductivity more than 5 micro-Seimens per cm.
 - c. Inherent bi-directional flow measurement.
 - d. Flow measurement with three pipe diameters upstream and two pipe diameters downstream.
 - e. Wet calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.
 - f. Transmitter integral to meter.
 - 3. Performance:
 - a. Accuracy for Velocities between 3.3 and 33 fps : Within 0.2 percent of reading.
 - b. Accuracy for Velocities between 1.0 and 3.3 fps : Within 0.75 percent of reading.
 - c. Accuracy for Velocities Less than 1.0 fps : Within 0.0075 fps.
 - d. Ambient Temperature: Minus 4 to plus 140 deg F.
 - e. Process Temperature: Minus 4 to 212 deg F.
 - f. Pressure: 225 psig.
 - 4. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - c. Isolated.
 - 5. Digital Output Signal: Two, programmable, digital/pulse outputs configurable for frequency, pulse, or directional flow.
 - 6. Operator Interface:
 - a. Keypad.
 - b. Digital Display: Multiple-line digital display of alphanumerical characters.
 - c. LED for normal and alarm operation.
 - 7. Construction:
 - a. Body: Type 316 stainless steel.
 - b. Body Liner Material: PTFE.
 - c. Flow Tube: Type 304 stainless steel.

- d. Connection: 150 Class flange Threaded Wafer.
- e. Electrodes: Type 316 stainless steel. Quantity determined by manufacturer based on application.
- f. Electronics Enclosure:
 - 1) Painted aluminum.
 - 2) Removable cover.
 - 3) NEMA 250, Type 6.

J. Insertion Electromagnetic Flow Meter:

- 1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. ONICON Incorporated.
- 2. Description:
 - a. No moving parts.
 - b. Suitable for flow measurement of fluids with electrical conductivity between 20 to 60000 micro-Seimens per centimeter.
 - c. Suitable for pipe sizes NPS 3 through NPS 72.
 - d. Wet calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.
 - e. Continuous auto-zero function.
 - f. Transmitter integral to meter.
- 3. Performance:
 - a. Flow Range: 0.25 to 20 fps.
 - b. Accuracy for Velocities between 2 and 20 fps : Within 1 percent of reading.
 - c. Accuracy for Velocities Less than 2 fps : Within 0.02 fps.
 - d. Ambient Temperature: Minus 5 to 150 deg F.
 - e. Process Temperature: 15 to 250 deg F.
 - f. Pressure: 400 psig.
- 4. Output Signals:
 - a. Field-selectable analog signals.
 - 1) Current Signal (Isolated): 4 to 20 mA.
 - 2) Voltage Signal (Isolated): Zero- to 10-V dc.
 - b. Digital Signal: Dry-contact closure signaling fault condition.
 - c. Frequency Signal: Zero- to 15-V peak pulse, zero to 500 Hz.
 - d. Scalable Pulse Output:
 - 1) Isolated solid-state dry contact.
 - 2) Contact Rating: 100 mA at 50-V dc.
 - 3) Pulse Duration: 0.5, 1, 2, or 6 seconds.
- 5. Construction:
 - a. Wetted Metal Parts: Type 316 stainless steel.
 - b. Sensor Head: Polysulfone.
 - c. Process Connection: 1-inch.
 - d. Instrument Isolation Valve: Full port Type 316 stainless steel ball valve for system isolation.
 - e. Electrodes: Type 316 stainless steel.
 - f. Electronics Enclosure:
 - 1) Painted aluminum.

- 2) Removable cover.
 - 3) NEMA 250, Type 4.
 - 4) Electrical Connection: PVC-jacketed cable, 10 feet long.
 - 5) Conduit Connection: 1/2-inch trade size.
6. Display Module:
- a. Remote from meter.
 - b. House in a NEMA 250, Type 4X enclosure.
 - c. Label terminal strip for all wiring connections.
 - d. 120-V ac power supply with 24-V dc output to power the flow sensor.
 - e. Input Signal from Meter: Zero- to 15-V pulse output.
 - f. Output Signals: Additional output signals furnished with flow meter connected to display module terminal strip.
 - g. Auxiliary Output Signals: Analog current output (isolated) shall be 4 to 20 mA.
 - h. Auxiliary Output Signals: Analog voltage output (isolated) shall be zero to 10 V.
 - i. Auxiliary Output Signals: Digital output (isolated) shall be solid-state dry contacts rated for 100 mA at 50 V.
 - j. Digital Display:
 - 1) Flow rate.
 - 2) Totalized flow.
 - 3) At least six display digits for flow rate and eight display digits for totalization.
 - 4) Bi-directional units with separate digital display for flow and totalization in each direction.
 - k. Local reset of flow totalization.
 - l. Program and data shall be stored in nonvolatile memory in the event of power loss.
 - m. For bi-directional units, provide LED display of flow direction (contacts open or closed).

K. Vortex Shedding Flow Meter with Integral Temperature Measurement:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. ONICON Incorporated.
2. Description:
 - a. Flow measurement using vortex shedder body with integral 1000-ohm platinum RTD.
 - b. Meter NPS 3/8 through NPS 8.
 - c. Each meter shall be factory calibrated at five points from zero to 250 fps and tagged accordingly against the manufacturer's flow standards. The manufacturer shall provide a certificate of calibration for meter.
 - d. Each meter shall be programmed using project-specific application data.
 - e. Meter shall include integral diagnostics to verify installation conditions and proper operation.
3. Performance:
 - a. Volumetric Flow Accuracy: Within 1 percent of reading for meter NPS 1 and larger; within 2 percent of reading for smaller sizes.
 - b. Mass Flow Accuracy: Within 1.5 percent of reading for NPS 1 and larger; within 2.5 percent of reading for smaller sizes.
 - c. Ambient Temperature: Zero to 132 deg F.
 - d. Process Temperature: 25 to 464 deg F.
 - e. Pressure: Equal to flange rating.
4. Output Signals:
 - a. Analog Current Signal of Flow Rate:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.

- b. Digital Signal: Pulse output for flow totalization. Two wire, scaled pulse, 0.5 Hz, 100 mA at 30-V dc.
- 5. Operator Interface:
 - a. Keypad.
 - b. Digital Display: Two-line digital display of alphanumerical characters. The meter shall display flow rate, flow totalization, and temperature and support field programming of all parameters.
- 6. Construction:
 - a. Material: Type 316L stainless steel for sizes through NPS 4 ; Type 304 stainless steel for larger sizes.
 - b. Connection: Class 300 flange.
 - c. Vortex Shedder: Unalloyed titanium.
 - d. Shedder Seal: Nickel-plated Inconel.
 - e. Enclosure:
 - 1) Epoxy-painted cast aluminum.
 - 2) Removable screw-on cover.
 - 3) NEMA 250, Type 4X.
 - 4) Electrical Connection: Screw terminals.
 - 5) Conduit Connection: Two, 1/2-inch trade size.
- 7. Remote Display Module:
 - a. Remote from meter.
 - b. House in a NEMA 250, Type 4 enclosure.
 - c. Label terminal strip for all wiring connections.
 - d. 120-V ac power supply with 24-V dc output to power the flow meter.
 - e. Input Signal from Meter: Analog current, 4 to 20 mA.
 - f. Output Signals:
 - 1) Analog Current Output: Two wire, 4 to 20 mA, maximum loop resistance 275 ohms.
 - 2) Digital Output (Isolated): Solid-state dry contacts rated for 100 mA at 50-V dc.
 - g. Digital Display:
 - 1) Flow rate.
 - 2) Totalized flow.
 - 3) Display Digits: 3.5 for flow rate and 8 for totalization.
 - h. Local reset of flow totalization.
 - i. Program and data shall be stored in nonvolatile memory in the event of power loss.
- 8. Upstream Flow Straightener:
 - a. Flow straightener where required by installation.
 - b. Straightener shall be wafer type, constructed of Type 304 stainless steel, designed to be installed between field-installed flanges.
 - c. Straightener size shall match meter size.
- L. Vortex Shedding Flow Meter with Integral Pressure and Temperature Measurement:
 - 1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. ONICON Incorporated.
 - 2. Description:
 - a. Mass flow measurement corrected for density using vortex shedder body with integral piezoelectric pressure sensors and 1000-ohm platinum RTD.

- b. Meter NPS 1/2 through NPS 12.
 - c. Each meter shall be factory calibrated at five points from Zero to 250 fps and tagged accordingly against the manufacturer's flow standards. The manufacturer shall provide a certificate of calibration for meter.
 - d. Each meter shall be programmed using project-specific application data.
 - e. Meter shall include integral diagnostics to verify installation conditions and proper operation.
- 3. Performance:
 - a. Volumetric Flow Accuracy for Liquid: Within 0.75 percent of reading for Reynolds numbers 20000 and larger.
 - b. Volumetric Flow Accuracy for Steam and Gas: Within 1 percent of reading for Reynolds numbers 20000 and larger.
 - c. Mass Flow Accuracy for Steam and Gas: Within 1.5 percent of reading for Reynolds numbers 20000 and larger.
 - d. Repeatability: Within 0.1 percent.
 - e. Long-Term Stability: Within 0.1 percent per year.
 - f. Ambient Temperature: Minus 40 to plus 185 deg F.
 - g. Process Temperature: Minus 40 to plus 464 deg F.
 - h. Pressure: Equal to flange rating.
- 4. Output Signals:
 - a. Analog Current Signal of Flow Rate:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.
 - b. Analog Current Signals for Pressure and Temperature: Separate 4- to 20-mA signals for gage pressure and temperature.
 - c. Digital Signal:
 - 1) Pulse output for flow totalization. Two wire, scaled pulse, 0.5 Hz, 100 mA at 30-V dc.
 - 2) HART, FSK protocol.
- 5. Operator Interface:
 - a. Keypad.
 - b. Digital Display: Two-line digital display of alphanumerical characters. The meter shall display flow rate, flow totalization, pressure, temperature, and support field programming of all parameters.
- 6. Construction:
 - a. Material: Type 316L stainless steel.
 - b. Connection: Class 150 flange.
 - c. Enclosure:
 - 1) Epoxy-painted cast aluminum.
 - 2) Removable screw-on cover.
 - 3) NEMA 250, Type 6.
 - 4) Electrical Connection: Screw terminals.
 - 5) Conduit Connection: Two, 1/2-inch trade size.
- 7. Upstream Flow Straightener:
 - a. Meter manufacturer shall provide flow straightener where required by installation to comply with manufacturer's installation recommendations.
 - b. Straightener shall be wafer type, constructed of Type 304 stainless steel, designed to be installed between field-installed flanges.
 - c. Straightener size shall match meter size.

M. Vortex Shedding Flow Meter for Hazardous Environments:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Rosemount; Emerson Process Management.
2. Standard: ASME MFC-6M.
3. Description:
 - a. FM Approved for hazardous environments.
 - 1) Intrinsically safe for Class I, Division 1, Groups A, B, C, and D; Class II and III, Division 1, Groups E, F, and G.
 - 2) Explosion-Proof for Class I, Division 1, Groups B, C, and D.
 - 3) Dust-Ignition-Proof for Class II and III, Division 1, Groups E, F, and G.
 - b. Sensor shall be isolated from process and replaceable without breaking process seals.
 - c. Meter immune to vibration.
 - d. Clog-free design eliminates gaskets and ports.
 - e. Meter NPS 1/2 through NPS 12.
 - f. Each meter shall be factory calibrated and provided with a certificate of calibration.
 - g. Meter shall be furnished with a permanently attached stainless steel tag.
 - h. Meter shall include integral diagnostics to verify proper operation.
4. Performance:
 - a. Flow Accuracy: Within 0.65 percent of reading plus 0.025 percent of span for Reynolds numbers 20000 and larger.
 - b. Repeatability: Within 0.1 percent of flow rate.
 - c. Long-Term Stability: Within 0.1 percent of flow rate per year.
 - d. Response Time: Greater of three vortex shedding cycles or 0.2 seconds.
 - e. Dampening: Adjustable between 0.2 to 255 seconds.
 - f. Ambient Temperature: Minus 58 to plus 250 deg F.
 - g. Humidity: Zero to 95 percent noncondensing.
 - h. Process Temperature: Minus 40 to plus 450 deg F.
 - i. Pressure: Equal to flange rating.
5. Output Signals:
 - a. Analog Current Signal of Flow Rate:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.
 - b. Digital Signal:
 - 1) Pulse output for flow totalization.
 - 2) HART protocol.
6. Digital Display: Digital display of alphanumeric characters. The meter shall display flow rate, flow totalization, percent of range, and current output.
7. Body and Flanges:
 - a. Material: Type 316L stainless steel.
 - b. Connection: ASME B16.5, Class 150 flange.
 - c. Enclosure:
 - 1) Polyurethane-painted cast aluminum.
 - 2) Removable screw-on cover.
 - 3) NEMA 250, Type 4X.
 - 4) Electrical Connection: Screw terminals.
 - 5) Conduit Connection: 1/2-inch trade size.

2.5 LIQUID FLOW TRANSMITTERS

A. Pressure Differential Transmitter with 0.07 Percent Accuracy for Flow Measurement :

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Rosemount; Emerson Process Management.
2. FM Approved for hazardous environments.
 - a. Intrinsically safe for Classes I, II, and III, Divisions 1 and 2, Groups A through H.
 - b. Explosion-Proof for Class I, Division 1, Groups B, C, and D.
 - c. Dust-Ignition-Proof for Class II, Division 1, Groups E, F, and G.
 - d. Dust-Ignition-Proof for Class III, Division 1.
3. Performance:
 - a. Range: Minus 250- to 250-inch wg.
 - b. Span: Field adjustable.
 - c. Minimum Span: 2.5-inch wg.
 - d. Accuracy: Within 0.07 percent of span or better.
 - e. Stability: Within 0.125 percent of upper range limit for 5 years.
 - f. Overpressure Limits: 3626 psig.
 - g. Process Temperature Limits: Minus 40 to plus 250 deg F.
 - h. Ambient Temperature Limits: Minus 40 to plus 185 deg F.
 - i. Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
 - j. Shock and vibration shall not harm the transmitter.
4. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - c. Digital signal based on HART protocol carried with current signal.
 - d. Dampening: Field selectable zero to 30 seconds.
5. Operator Interface: Zero and span adjustments located behind cover.
6. Display: Five-digit, two-line digital display with 0.4 inch high alphanumeric characters.
7. Construction:
 - a. Nonwetted parts of transmitter constructed of aluminum or stainless steel.
 - b. Enclosure with removable cover on each side.
 - c. Wetted parts of transmitter constructed of Type 316 stainless steel.
 - d. NPS 1/2 process connections on bottom of instrument.
 - e. Drain/vent valve on low- and high-pressure connections.
 - f. Two 1/2-inch trade size conduit connection on side of instrument enclosure.
 - g. Screw terminal block for wire connections.
 - h. NEMA 250, Type 4X.
 - i. Mounting bracket suitable for installation.
8. Five-Valve Manifold:
 - a. Each transmitter shall have integrally mounted manifold.
 - b. Construct manifold body of Type 316 stainless steel.
 - c. Manifold shall have NPS 1/2 process connections.

B. Liquid Pressure Differential Transmitter for Flow Measurement:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Dwyer Instruments, Inc.
2. Performance:

- a. Range: Approximately 2 times the set point.
 - b. Span: Adjustable plus or minus 1 mA, non-interactive.
 - c. Accuracy: Within 0.25 percent of full scale.
 - d. Maximum Operating Pressure: 2.5 times range.
 - e. Temperature Limits: Zero to 175 deg F.
 - f. Compensate Temperature Limits: 30 to 150 deg F.
 - g. Thermal Effects: 0.02 percent of full scale per degree F.
 - h. Response Time: 30 to 50 ms.
 - i. Shock and vibration shall not harm the transmitter.
3. Analog Output Current Signal:
 - a. Two wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
4. Operator Interface:
 - a. Zero and span adjustments located behind cover.
 - b. Bleed screws on side of body, two screws on low-pressure side and one screw on high-pressure side, for air in line and pressure cavity.
5. Construction:
 - a. Aluminum and stainless steel enclosure with removable cover.
 - b. Wetted parts of transmitter constructed of 17-4 PH or 300 series stainless steel.
 - c. NPS 1/4 process connections on side of instrument enclosure.
 - d. Knock out for 1/2-inch trade size conduit connection on side of instrument enclosure.
 - e. Screw terminal block for wire connections.
 - f. NEMA 250, Type 4X.
 - g. Mounting bracket shall be suitable for installation.
6. Transmitter shall have three-valve manifold. Construct manifold of brass, bronze, or stainless steel. Manifold shall have NPS 1/4 process connections.

2.6 THERMAL MASS FLOW METER

- A. Products: Subject to compliance with Requirements/Specifications of, American Made, Buy America Act FAR 52.225.1 ASHREA 62, UL 61010-1/CSA S22.2 no 61010-1 Part 1, CAN/CSA-C22.2 No 157-02 classified locations, CSA C22.2 No 213-M1987 Class 1, Division. 2 Hazardous locations, ATEX Ex, NA IIC T4X
- B. Basis of design: ONICON F-5400, F-5500, F-5500-5 Thermal Mass meter
- C. Applications:
 1. Natural Gas, Propane, Land Fill Gas
 2. Compressed Air
 3. Other Combustible Gases
 4. Industrial Gases
- D. Description:
 1. Thermal Mass Flow Meter, shall be complete with all installation hardware necessary to enable insertion and removal with system shut down shall be provided by the flow meter manufacture.
 2. Suitable for pipe sizes Insertion; 1 ½ – 36 inch, Inline; ¾ - 4 inch
 3. No moving parts, analog/digital thermal dispersion technology
 4. Flow Rangers 5 to 35,000 SFPM

5. Calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.
6. Transmitter integral to meter.

E. Sensor:

1. Operating Pressure: <500 PSIG
2. Process Temperature: -40° to 200° F
3. Sensors: 316L, sheath over platinum grade RTD's
4. Wetted components: 316 Stainless Steel

F. Transmitter:

1. Electronics Enclosure shall have:
 - a. Integral mounted
 - b. Painted aluminum, NEMA 4 enclosure.
 - c. Removable cover
 - d. Labeled terminal strip for wiring connections
 - e. Conduit Connection: ½ inch trade size.
 - f. Ambient Temperature: -40 to 150 deg. F.
2. Power:
 - a. 24 Vdc ± 10 %
3. Output Signals shall be:
 - a. Current Signal: 4 to 20 mA.
 - b. Voltage Signal: Zero- to 5 or 10-V dc.
 - c. Frequency Signal: Zero- to 15-V peak pulse, zero to 500 Hz.
 - d. Scalable Pulse Output:
 - 1) Isolated solid-state dry contact.
 - 2) Contact Rating: 100 mA at 50-V dc.
 - e. Protocol: BACnet MSTP MODBUS RTU RS 485
4. Digital Display shall have:
 - a. Flow rate and totalized flow.
 - b. High contrast photo emissive OLED graphical display
 - c. Six display digits for flow rate and eight display digits for totalization

G. Accuracy shall be:

1. Natural Gas:
 - a. ± 1 of readings for velocities between 500 to 7000 SFPM
 - b. ± 2 of readings for velocities between 100 to 500 SFPM
2. Compressed Air and other high velocity:
 - a. ± 1 of readings + 0.5% of scale when over 100:1 turndown.

H. Warranty:

1. The flow meter shall be covered by the manufacturer's three-year warranty

I. Installation:

1. The flow meter shall be installed according to manufacturer's recommendations.
2. See installation detail on mechanical drawing details
3. Remote mount display as required by drawings
4. Hand insert-able up to 1000 PSIG.
5. Provide a flow conditioner, if required to meet the manufacturer's minimum upstream straight pipe run requirement.

J. BAS Interface:

1. Provide ONICON Model D-100 Series BAS Interface
2. 24V
3. Power from the display to power the flow meter.
4. House in a NEMA 13 enclosure.
5. Serial Communication Interface: Compatible with host to share flow rate and totalized flow data. N2 Modbus RTU Modbus TCP/IP BACnet MSTP BACnet IP Analog outputs
6. Digital display for flow rate and totalized flow.
7. At least eight display digits for totalization.
8. Local reset of flow totalization
9. Program and data shall be stored in nonvolatile memory in event of power loss.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Provide the services of an independent inspection agency to confirm that proposed mounting locations comply with requirements indicated and approved submittals.
 1. Indicate dimensioned locations with mounting height for all surface-mounted products to walls and ceilings on shop drawings.
 2. Do not begin installation without submittal approval of mounting location.
- E. Complete installation rough-in only after confirmation by independent inspection is complete and approval of location is documented for review by Owner and Architect on request.
- F. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- G. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy more stringent of all requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.

- C. Install ceiling, floor, roof, and wall openings and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- D. Install products in locations that are accessible and that will permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- E. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they will be subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments, including, but not limited to, the following:
 - a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
 - 3. When conduit is in contact with a corrosive environment, use Type 316 stainless steel conduit and fittings or conduit and fittings with a corrosive-resistant coating that is suitable for environment.
 - 4. Where instruments are located in a corrosive environment and are not corrosive resistant from the manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 INSTRUMENTS, GENERAL INSTALLATION REQUIREMENTS

- A. Mounting Location:
 - 1. Rough-in: Outline instrument-mounting locations before setting instruments and routing cable, wiring, tubing, and conduit to final location.
 - 2. Install switches and transmitters for air and liquid flow associated with individual air-handling units and connected ductwork and piping near air-handlings units co-located in air-handling unit system control panel, to provide service personnel a single and convenient location for inspection and service.
 - 3. Install liquid and steam flow switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 - 4. Install airflow switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 - 5. Mount switches and transmitters not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use

- manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
6. Install instruments in steam, liquid, and liquid-sealed-piped services below their process connection point. Slope tubing down to instrument with a slope of 2 percent.
 7. Install instruments in dry gas and non-condensable-vapor piped services above their process connection point. Slope process connection lines up to instrument with a minimum slope of 2 percent.

B. Mounting Height:

1. Mount instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
2. Mount switches and transmitters, located in mechanical equipment rooms and other similar space not subject to code, state, and federal accessibility requirements, within a range of 42 to 72 inches above the adjacent floor, grade, or service catwalk or platform.
 - a. Make every effort to mount at 60 inches.

C. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.

3.5 FLOW INSTRUMENTS INSTALLATION

A. Airflow Sensors:

1. Install sensors in straight sections of duct with manufacturer-recommended straight duct upstream and downstream of sensor.
2. Installed sensors shall be accessible for visual inspection and service. Install access door(s) in duct or equipment located upstream of sensor, to allow service personnel to hand clean sensors.

B. Liquid Flow Meters:

1. Install meters in straight sections of piping with manufacturer-recommended straight piping upstream and downstream of sensor.
2. Install pipe reducers for in-line meters smaller than line size. Install reducers at distance from meter to avoid interference and impact on accuracy.
3. Install in-line meters with flanges or unions to provide drop-in and -out installation.
4. Insertion Meters:
 - a. Install system process connections full size of meter connection, but not less than NPS 1. Provide stainless steel bushing if required to mate to system connection.
 - b. Install meter in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement.
 - c. In applications where top-dead-center location is not possible due to field constraints, install meter at location along top half of pipe if acceptable by manufacturer for mounting orientation.

C. Transmitters:

1. Install airflow transmitters serving an air system in a single location adjacent to or within system control panel.
2. Install liquid flow transmitters, not integral to sensors, in vicinity of sensor. Where multiple flow transmitters serving same system are located in same room, co-locate transmitters by system to provide service personnel a single and convenient location for inspection and service.

3.6 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification and on face of ceiling directly below instruments concealed above ceilings.

3.7 CLEANING

- A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.
- B. Wash and shine glazing.
- C. Polish glossy surfaces to a clean shine.

3.8 CHECKOUT PROCEDURES

- A. Description:
 - 1. Check out installed products before continuity tests, leak tests, and calibration.
 - 2. Check instruments for proper location and accessibility.
 - 3. Check instruments for proper installation with respect to direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
 - 4. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.
- B. Flow Instrument Checkout:
 - 1. Verify that sensors are installed correctly with respect to flow direction.
 - 2. Verify that sensor attachment is properly secured and sealed.
 - 3. Verify that processing tubing attachment is secure and isolation valves have been provided.
 - 4. Inspect instrument tag against approved submittal.
 - 5. Verify that recommended upstream and downstream distances have been maintained.

3.9 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 - 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 - 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
 - 3. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
 - 4. Equipment and procedures used for calibration shall meet instrument manufacturer's recommendations.
 - 5. Provide diagnostic and test equipment for calibration and adjustment.
 - 6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.

7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
8. If after-calibration-indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

E. Switches: Calibrate switches to make or break contact at set points indicated.

F. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.10 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.14

SECTION 230923.16 - GAS INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes the Following Gas Instruments:
 - 1. Carbon-dioxide sensors and transmitters.
 - 2. Combination carbon-dioxide and VOC sensors and transmitters.
 - 3. Single-point oxygen monitoring system.
 - 4. Multipoint carbon-monoxide monitoring system.
 - 5. VOC sensors and transmitters.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.16.

1.3 DEFINITIONS

- A. NDIR: Nondispersive infrared.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 2. Installation instructions, including factor affecting performance.
 - 3. Product description with complete technical data, performance curves, product specification sheets.
- B. Shop Drawings:
 - 1. Include plans, elevations, sections, and mounting details.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For gas instruments to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 CARBON-DIOXIDE SENSORS AND TRANSMITTERS

- A. Manufacturers: Subject to compliance with requirements, provide products by the following:
1. Telaire; a brand of Amphenol Thermometrics Inc.
- B. Description:
1. NDIR technology or equivalent technology providing long-term stability and reliability.
 2. Two-wire, 4-20 mA output signal, linearized to carbon-dioxide concentration in ppm.
- C. Construction:
1. House electronics in an ABS plastic enclosure. Provide equivalent of NEMA 250, Type 1 enclosure for wall-mounted space applications and NEMA 250, Type 4 for duct-mounted applications.
 2. Equip with digital display for continuous indication of carbon-dioxide concentration.
- D. Performance:
1. Measurement Range: Zero to 2000 ppm.
 2. Accuracy: Within 2 percent of reading, plus or minus 30 ppm.
 3. Repeatability: Within 1 percent of full scale.
 4. Temperature Dependence: Within 0.05 percent of full scale over an operating range of 25 to 110 deg F.
 5. Long-Term Stability: Within 5 percent of full scale after more than five years.
 6. Response Time: Within 60 seconds.
 7. Warm-up Time: Within five minutes.
- E. Provide calibration kit. Turn over to Owner at start of warranty period.

2.2 COMBINATION CARBON-DIOXIDE AND VOC SENSORS AND TRANSMITTERS

- A. Description:
1. NDIR technology or equivalent technology that provides long-term stability and reliability.
 2. Senses and responds to combined concentration of more than 30 contaminants commonly found in indoor environments.
- B. Output Signal: Zero to 10-V dc.
- C. Performance:
1. Carbon-Dioxide Range: Zero to 2000 ppm.
 2. Carbon-Dioxide Accuracy: Within 50 ppm, plus 2 percent measured value.
 3. VOC Range: Zero to 2000 ppm.
 4. VOC Sensitivity Ranges: Field selectable, low, normal, high.
 5. Ambient Temperature: 32 to 122 degrees F.
 6. Ambient Relative Humidity: 5 to 95 percent non-condensing.

- D. Enclosure: White plastic.
- E. Electrical Connections: Screw terminals.
- F. Display: Digital, LCD.

2.3 SINGLE-POINT OXYGEN MONITORING SYSTEM

- A. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - 1. MSA Instrument Division.
- B. Description:
 - 1. System shall measure and display a single gas concentration, provide local audio and visual alarms when preset limits are exceeded, and send output signals of gas concentration and detected alarms.
 - 2. System shall require no periodic maintenance other than periodic checking of sensor response to a known concentration of gas.
 - 3. System shall be designed to provide for installation, setup, and start-up from outside of unit enclosure without need to open the enclosure door.
 - 4. System shall be factory calibrated and ready for operation after installation.
 - 5. Monitor shall be internally wired to accommodate a single-point field power connection.
- C. Performance:
 - 1. Range: Full scale, zero to 25 percent oxygen.
 - 2. Zero Drift: Within 1 percent per year.
 - 3. Span Drift: Within 10 percent per year.
 - 4. Repeatability: Within 1 percent of full scale.
 - 5. Linearity: Within 2 percent of full scale.
 - 6. Step Change Response Time: Within 12 seconds.
- D. Enclosure:
 - 1. NEMA 250, Type 4X.
 - 2. Access to the inside of enclosure, as well as to controller, display, and wiring connections, shall be through full-length door on front of enclosure.
 - 3. Door with shatterproof window sized to provide viewing of visual display and indicator lights.
 - 4. Equip enclosure with mounting brackets for the purpose of attaching the unit to a flat surface.
 - 5. Provide door with key lock access to inside enclosure.
- E. Controller:
 - 1. Password-protected access through full-function keypad.
 - 2. Set:
 - a. Real-time clock.
 - b. Alarm levels.
 - c. Change span-gas values.
 - d. Display date of last calibration.
 - e. Display minimum, maximum, and average gas values.
 - f. Change address, future calibration time, and date.
 - 3. Automatic return-to-normal-operation feature after calibration.
 - 4. Date stamps last successful calibration.

5. Time and date stamps events.
6. Selectable lockout of output signals during calibration.
7. Logs minimum, maximum, and average gas concentrations over selected time intervals.

F. Visual Display:

1. Four-digit LED or backlight LCD display visible from front face of enclosure.
2. Value displayed shall be a direct reading of gas concentration.
3. Displays system status indicators.
4. Visual Alarm Indication:
 - a. Three separate alarm levels: Caution, Warning, and Alarm.
 - b. Separate strobes for Warning and Alarm conditions. Externally mount the two strobes on top of enclosure.
5. Indication of sensor nearing end of its useful life based on the sensor output, not on the time the sensor was in service.
6. Displays average, minimum, and maximum gas concentrations of the sensor over selected time.
7. Malfunction Indication Alarm: Displays a separate unique character when an over range or under range condition exists, a sensor signal sensor is lost, or a set-point error or memory failure occurs.

G. Audible Alarm:

1. Provides an audible horn when an alarm condition occurs.
2. Horn shall be rated for 95 dB with selectable output tones.
3. Mount horn inside or on exterior of enclosure.
4. Activate horn through a horn relay. Horn relay shall be form "A" contacts and set as normally open and common.

H. Operator Interface:

1. Door Audible Alarm Acknowledge Switch:
 - a. Push-button switch located on front door shall silence audible alarm.
 - b. Switch shall reset latched alarms if normal gas conditions exist. Visual alarms shall remain on as long as alarms are exceeded.
2. Operating Modes and Parameters Selection: Selections listed shall be accomplished by the use of switches, jumpers, or remote control not involving the use of tools.
 - a. Display range value.
 - b. Latching or nonlatching mode for the alarm set points.
 - c. Upscale or downscale acting alarms.

I. Output Signal:

1. Relays:
 - a. Provide one relay for each set-point level for each of the three alarm levels.
 - b. Provide one relay for fault conditions.
 - c. Alarm and fault relays shall be form "C," SPDT. Contacts shall be rated for 5 A resistive at 250-V ac or 30-V dc.
 - d. Contacts shall be capable of being selected normally open or normally closed.
 - e. Alarm relays shall be normally de-energized. The fault relay shall be normally energized.

2. Digital Communication:

- a. Bidirectional sending and receiving of digital signals.
- b. Digital signals shall comply with FTT-10-based communication.
- c. Protocol shall be LonTalk supported by Lon Works.
- d. Signal speed shall be no greater than 78.1 kBs per second.

J. Sensor:

1. Electrochemical fuel-cell type does not require periodic addition of reagents.
2. Sensor shall be replaceable without the need for tools.
3. Sensors shall have a minimum useful life of one year. Replace failed sensors at no charge within first year.
4. Mount sensor externally on the side or bottom of enclosure. Where indicated on Drawings, mount sensor remote from enclosure.
5. Remote Mounting:
 - a. Provide sensor in a separate enclosure. Enclosure shall be NEMA 250, Type 4X, except when sensor is installed in a hazardous location, then enclosure shall be an explosion-proof type suitable for the application.
 - b. Provide sensor with cable for connecting to monitor.
 - c. Provide sensor with mounting hardware suitable for application.
 - d. For duct-mounted applications, the sensor installation shall provide kit for calibration of the sensor without removing sensor from duct.

K. Gas Sampling Pump:

1. Where required by application, provide a pump mounted inside the enclosure to provide a motive force to induce flow of gas sample across the sensor.
2. Signal to the sensor from the pump shall be in digital communication format to eliminate radio-frequency interference (RFI) and electromagnetic interference (EMI).
3. A flow sensor shall activate a relay when the gas sample falls below the acceptable flow rate to the sensor and shall indicate a loss of gas flow on the display.
4. Introduction of a calibration gas to the gas sensor shall be through an integral push-button valve. This push-button valve shall return to monitoring the sampled area when released.

L. Calibration:

1. Calibrate and adjust functions through nonintrusive hand-held wireless remote control without opening enclosure door.
2. Enter calibration mode through hand-held wireless remote control unit. The display of the monitor shall instruct the user on when to apply zero and span gas. The system shall automatically adjust its internal settings to the proper calibration values without further intervention by the user. On completion of a successful calibration, the system shall exit the calibration mode. Date stamp of last successful calibration is retained in the system internal memory, with capability to be indicated on display. If calibration is unsuccessful for any reason, the display shall show an unsuccessful calibration attempt and revert to its previous calibration settings.
3. Wireless method shall employ a digitally encoded infrared light beam.
4. Hand-held wireless remote control shall let the user perform sensor zeroing and calibration, as well as activate all functions and features of the monitor.
5. The monitor infrared link shall not be affected by natural and man-made low-level ambient light.

M. Automatic Calibration System:

1. Provide automatic calibration of all oxygen monitors installed. Number of automatic calibration systems shall be determined by supplier based on location and quantity of oxygen monitors.
2. Automatic calibration system shall, without manual intervention, periodically perform a complete calibration of the sensor.
3. System shall exchange digital signals with sensor.
4. Automatic calibration shall be adjustable from as many as three times per day to only once every 30 days.
5. Sensor alarms shall be suppressed or disabled until the automatic calibration cycle is completed.
6. Manual calibration of the sensor shall be initiated at any time with a hand-held infrared remote control without the need to disable or turn off the automatic calibration system.
7. House the system in a separate NEMA 250, Type 4X enclosure from the oxygen monitoring system. Enclosure shall have provisions for wall mounting.
8. Digital displays shall indicate zero and when span gas is being applied to the sensor, the status, and any fault condition.
9. Provide with a separate valve conduit to monitor the condition of the calibration cylinders attached to the calibration system. Insufficient gas pressure to calibrate the sensor shall light the fault indicator.

2.4 MULTIPOINT CARBON-MONOXIDE MONITORING SYSTEM

A. Manufacturers: Subject to compliance with requirements, undefined:

1. MSA Instrument Division.

B. Description:

1. Each sampling point shall monitor any variation in the carbon-monoxide concentration level.
2. Each sampling point shall be individually piped to the monitoring system.
3. Provide each sampling point with a 0.3-micron filter.
4. Each sampling point shall be an alarm point.
5. A dual-head diaphragm pump shall draw an air sample through piping system and through a microprocessor-controlled sequencer feeding an analyzer with a new sample every 15 seconds.
6. Sample time shall be adjustable in 1 second increments from zero to 60 minutes.
7. Span and zero calibration gas shall be automatically initiated by the microprocessor. System shall also provide manual initiation of span and zero calibration gas.
8. Analyzer output shall be corrected by the microprocessor.
9. Monitoring system shall have 32 sample points.
10. System shall operate on 120-V ac, single-phase, 60-Hz power.
11. Final adjustment; calibration, testing, and startup of the system shall be performed by a trained representative of manufacturer.

C. Analyzer:

1. Analyzer shall operate using principle of nondispersive infrared absorption.
2. Sampling response time shall be within 10 seconds.
3. Zero drift and span drift shall be less than 1 percent of full scale within a 24-hour period.
4. Repeatability shall be within 1 percent of full scale.
5. Accuracy shall be within 1 percent of full scale.
6. Calibration range shall be zero to 500 ppm.
7. Digital display on analyzer face with scale shall be in ppm.
8. Temperature shall be compensated from 30 to 120 deg F ambient temperature.

D. Control and Display:

1. Each sample shall send a 4-20 mA output signal proportional to the highest concentration.
2. Alphanumeric visual display of current analyzer concentration reading shall be in ppm or another industry-accepted measurement.
3. Visual indication for sample analyzing, sample high-concentration alarm, analyzer malfunction, and calibration.
4. Any number and configuration of sample points shall be capable of being bypassed.
5. Each sample point shall be capable of being manually sampled through an override feature.
6. System parameters shall be stored in nonvolatile memory.
7. Provide at least an eight-hour battery backup of current alarm status. Battery shall be rechargeable.

E. Enclosure:

1. NEMA 250, Type 1.
2. Hinged and locking door, full size of face.
3. House all system components. Multiple adjoining enclosures are acceptable if joined to a common support structure.

F. Calibration Equipment:

1. Provide equipment necessary to automatically and manually calibrate the system, including, but not be limited to, the following:
 - a. Regular assembly.
 - b. Zero cap.
 - c. Calibration cap.
 - d. Two cylinders filled with calibration gas.
 - e. Instruction book.
 - f. Carrying case.

2.5 VOC SENSORS AND TRANSMITTERS

A. Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Building Automation Products Inc.; BAPI.

B. Description:

1. VOC sensor shall use an oxidizing element that varies resistance with contaminant gases.
2. Senses and responds to combined concentration of more than 30 contaminants commonly found in indoor environments.

C. Output Signal: Zero to 10-V dc with minimum load resistance of 4000 ohms.

D. Performance:

1. Measurement Range: Zero to 100 percent.
2. Ambient Temperature: 32 to 140 deg F.
3. Ambient Relative Humidity: 5 to 95 percent non-condensing.

E. Enclosure: Lexan.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Furnish and install products required to satisfy more stringent of all requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Properly support instruments, tubing, piping, wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement and sway or a break in attachment when subjected to seismic loads.
- D. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by using excessive force or oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- E. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- F. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they are subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments, including but not limited to, the following:
 - a. Laboratory exhaust airstreams.
 - b. Process exhaust airstreams.
 - 3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 - 4. Where instruments are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRICAL POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 INSTRUMENTS, GENERAL INSTALLATION REQUIREMENTS

- A. Mounting Location:
 - 1. Install transmitters for gas associated with individual air-handling units and associated connected ductwork and piping near air-handlings units co-located in air-handling unit system control panel, to provide service personnel a single and convenient location for inspection and service.
 - 2. Install gas switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 - 3. Mount switches and transmitters not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer's mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
 - 4. Install instruments in dry gas and non-condensable vapor piped services above their process connection point. Slope process connection lines up to instrument with a minimum slope of 2 percent.
- B. Mounting Height:
 - 1. Mount instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
 - 2. Mount switches and transmitters located in mechanical equipment rooms and other similar space not subject to code, state, and federal accessibility requirements within a range of 42 to 72 inches above the adjacent floor, grade, or service catwalk or platform.
 - a. Make every effort to mount at 60 inches.
- C. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated, using neoprene gaskets or grommets.

3.5 CARBON-MONOXIDE MONITORING SYSTEM

- A. Install sample points in monitored area to provide accurate measurement of gas concentration.
- B. Install exposed sampling points with a finished appearance consistent with other materials in space. Submit proposed products to be installed for review and approval.
- C. Individually install each sample point to the carbon-monoxide monitoring system.

- D. Install tubing in a minimum size of NPS 3/8.
- E. Use compression fittings at connections to equipment.
- F. If not indicated on Drawings, locate carbon-monoxide monitoring system in a secured and serviceable location accessible to authorized personnel.
- G. Support carbon-monoxide monitoring system from floor or wall. Support floor-mounted systems using a structural channel frame. Provide mounting brackets.

3.6 OXYGEN MONITORING SYSTEM

- A. Install monitor in space to provide an accurate measurement of gas concentration.
- B. Support oxygen monitoring system from wall.

3.7 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification on face.

3.8 CHECKOUT PROCEDURES

- A. Check out installed products before continuity tests, leak tests, and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that impact performance.
- D. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.

3.9 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 - 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 - 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
 - 3. For each analog instrument, perform a three-point calibration test for both linearity and accuracy.
 - 4. Equipment and procedures used for calibration shall comply with instrument manufacturer's written recommendations.
 - 5. Provide diagnostic and test equipment for calibration and adjustment.
 - 6. Field instruments and equipment used to test and calibrate installed instruments shall have an accuracy of at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.

7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
8. If, after calibration, indicated performance cannot be achieved, replace out-of-tolerance instruments.
9. Comply with field-testing requirements and procedures in ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

B. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Meters: Check sensors at zero, 50, and 100 percent of Project design values.

E. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

F. Switches: Calibrate switches to make or break contact at set points indicated.

G. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.10 DEMONSTRATION

- A. Train Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate gas instrument demonstration video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.16

SECTION 230923.17 - LEVEL INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes liquid-level switches, sensors, and transmitters.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.17.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include operating characteristics; electrical characteristics; and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 2. Include product description with complete technical data, performance curves, and product specification sheets.
- B. Shop Drawings:
 - 1. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For level instruments, to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Environmental Conditions:

1. Instruments shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.

2.2 LEVEL SWITCHES

A. Liquid-Level Switch (Magnetic Type with Float):

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. W. E. Anderson; Dwyer Instruments, Inc.
2. Description:
 - a. Mounting Suitable for Application: Horizontal or vertical switch mounting.
 - b. Float arm with hinge design limits vertical movement to prevent sticking.
 - c. Replaceable float with threaded connection.
 - d. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous environments (Class I, Groups C and D; Class II, Groups E, F, and G).
3. Performance:
 - a. Level Actuation and De-Actuation: 0.75-inch deadband.
 - b. Body Pressure Limit: 1000 psig for brass body; 2000 psig for Type 316 stainless-steel body.
 - c. Float Pressure Limit: 150 psig.
 - d. Temperature Range: Minus 4 to 275 deg F.
 - e. Electrical Rating: 10 A at 125/250-V ac.
 - f. Switch Type: DPDT snap switch.
4. Wetted Parts Construction:
 - a. Float and Rod: Type 316 stainless steel.
 - b. Body: Type 316 stainless steel.
 - c. Magnetic Keeper: Type 316 stainless steel.
 - d. Process Connection: NPS 1-1/2 NPT.
 - e. Enclosure:
 - 1) Die-cast aluminum alloy.
 - 2) Threaded cover.
 - 3) NEMA 250, Type 4.
 - 4) Electrical Connection: Terminal block.
 - 5) Conduit Connection: NPS 3/4 NPT.

B. Electrode-Type Liquid-Level Switches:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Proximity Controls; Dwyer Instruments, Inc.
2. Description:
 - a. Conductivity technology.
 - b. Dual point level settings.
 - c. No moving parts.
 - d. Adjustable sensitivity.
3. Performance:
 - a. Pressure Limit: 30 psig.
 - b. Temperature Limit: 212 deg F.
 - c. Power Supply: 120-V ac, 50 or 60 Hz.
 - d. Electrical Rating: 5 A at 240-V ac.
 - e. Switch Type: SPDT snap switch.
4. Probes:
 - a. Electrodes: 0.125-inch diameter.
 - b. Material: Type 316 stainless steel.
 - c. Length: To suit application up to 72 inches.
 - d. Process Connection: NPS 1 NPT.
 - e. Enclosure:
 - 1) Polypropylene.
 - 2) NEMA 250, Type 6.
 - 3) Electrical Connection: Cable and standard octal socket.

C. RF Admittance-Type Liquid-Level Switches:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Proximity Controls; Dwyer Instruments, Inc.
2. Description:
 - a. Capacitive technology.
 - b. No moving parts.
 - c. Not affected by sticky, dusty, or clingy materials that coat or build up on probe.
 - d. Immune to external radio frequency (RF) sources.
 - e. Sensitivity: Eight selectable settings.
 - f. Mounting: Horizontal or vertical.
3. Performance:
 - a. Pressure Limit: 365 psig.
 - b. Ambient Temperature Range: Minus 40 to 185 deg F.
 - c. Process Temperature Range: Minus 40 to 250 deg F.
 - d. Universal Power Supply: 12- to 240-V ac and dc.
 - e. Electrical Rating: 8 A at 120- and 240-V ac.
 - f. Switch Type: SPDT snap switch, selectable for normally open or closed operation.

- g. Response Time: 0.2 seconds.
 - h. Time Delay: Adjustable, zero to 60 seconds.
- 4. Probes:
 - a. Material: Type 316 stainless steel.
 - b. Insulator Material: PVDF.
 - c. Length: To suit application up to 72 inches.
 - d. Process Connection: NPS 1 NPT.
 - e. Enclosure:
 - 1) NEMA 250, Type 4X.
 - 2) Electrical Connection: Screw terminals on removable terminal block.
 - 3) Conduit Connection: NPS 1/2 NPT.

2.3 LEVEL TRANSMITTERS

A. RF Admittance-Type Liquid-Level Sensor and Transmitter:

- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. AMETEK, Inc.
- 2. Description: Complete package with electronic unit, sensing element, connecting cable.
 - a. Continuous level transmitter shall produce an output signal that is proportional to level.
 - b. Measurement shall be free from effects of changes in temperature, density, or acoustic noise in vapor space above level.
 - c. Continuous measurement shall be independent of changes in material density and unaffected by presence of material clinging to sensing element.
 - d. No moving parts and no routine cleaning and recalibration necessary.
 - e. Electronic unit shall be integral to sensing element or mounted remotely up to 100 feet away from sensor.
 - f. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for hazardous environments (Class I, Groups C and D; Class II, Groups E, F, and G).
- 3. Sensor:
 - a. Material: Teflon-coated Type 316 stainless steel.
 - b. Length: To suit installation.
 - c. Connection: NPS 3/4 NPT or flanged.
- 4. Electronic unit housed in NEMA 250, Type 4X enclosure.
 - a. Calibrated Range: Varies with application. At least 20 percent beyond high- and low-level set point and alarm levels.
 - b. Accuracy: Within 1 percent of calibrated range.
 - c. Two wire, loop powered.
 - d. Supply Voltage: 11.5 to 50-V dc.
 - e. Maximum Load: 625 ohms at 24-V dc.
 - f. Output Signal: 4 to 20 mA dc.
 - g. Response Time: 0.5 to 30 seconds, adjustable.
 - h. Temperature Range: Minus 40 to 165 deg F.
 - i. Zero and Span Adjustments: Non-interacting.

- j. Visual Indication: Continuous digital display of level.
- k. Field-changeable failsafe condition and phasing in event measurement requires changes to optimize level reading.
- l. Free from effects of radio frequency interference.
- m. Free from harmful effects of static electricity on sensing element with discharges of up to 10 A without damage.
- n. Adjustable time delay (signal dampening).

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments to verify actual locations of connections before installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by using excessive force or oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- C. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- D. Mount switches and transmitters not subject to code, state, and federal accessibility requirements within a range of 42 to 72 inches above the adjacent floor, grade or service catwalk, or platform.
 - 1. Make every effort to mount at 60 inches.

3.3 ELECTRICAL POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 LEVEL INSTRUMENTS INSTALLATION

- A. Mounting Location: Rough-in instrument-mounting locations before setting instruments and routing, cable, wiring, tubing, and conduit to final location.

3.5 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification on face.

3.6 CHECKOUT PROCEDURES

- A. Check out installed products before continuity tests, leak tests, and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of elevation, orientation, insertion depth, or other applicable considerations that impact performance.

3.7 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 - 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 - 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
 - 3. For each analog instrument, perform a three-point calibration test for both linearity and accuracy.
 - 4. Equipment and procedures used for calibration shall comply with instrument manufacturer's written recommendations.
 - 5. Provide diagnostic and test equipment for calibration and adjustment.
 - 6. Field instruments and equipment used to test and calibrate installed instruments shall have an accuracy of at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
 - 7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
 - 8. If, after calibration, indicated performance cannot be achieved, replace out-of-tolerance instruments.
 - 9. Comply with field-testing requirements and procedures in ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.
- B. Analog Signals:
 - 1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
 - 2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.

3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

C. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

D. Switches: Calibrate switches to make or break contact at setpoints indicated.

E. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.8 DEMONSTRATION

- A. Train Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate level instrument demonstration video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.17

SECTION 230923.18 - LEAK-DETECTION INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes the following types of leak-detection switches:
 - 1. Point-type, leak-detection switches.
 - 2. Cable-type, leak-detection switches.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.18.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Operating characteristics, electrical characteristics, and furnished accessories indicating control signal, default control signal with loss of power, and electrical power requirements.
 - 2. Product description with complete technical data and product specification sheets.
 - 3. Installation operation and maintenance instructions including factors affecting performance.
- B. Shop Drawings:
 - 1. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: To include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 LEAK-DETECTION SWITCHES

A. Point-Type, Leak-Detection Switches:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. RectorSeal HVAC; a CSW Industrials Company.
 - b. Veris Industries.
 - c. W.E. Anderson; a division of Dwyer Instruments, Inc.
2. Features: Audible and visual alarm with relay output for remote indication.
3. Alarm activated based on change in resistance.
4. Performance:
 - a. Service: Water.
 - b. Temperature Limits: 32 to 122 deg F.
 - c. Switch Type: SPDT relay.
 - d. Electric Connection: Cable attached.
5. Construction: Acrylic, ABS plastic.
6. Field Power: 24-V ac or dc.

B. Cable-Type, Leak-Detection Switches:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. W.E. Anderson; a division of Dwyer Instruments, Inc.
2. Control Module Features:
 - a. Power and alarm LEDs.
 - b. Alarm test switch.
 - c. Continuous tape integrity self check.
3. Performance:
 - a. Service: Water, or other conductive liquid.
 - b. Switch Type: DPDT.
 - c. Electric Connection: Screw terminals.
 - d. Conduit Connection: 0.5 inch.
4. Construction:
 - a. Control Module Enclosure: Extruded aluminum.
 - b. Tape: Hydrophobic with connector on each end.
 - c. Tape Length: 25 feet. Field extendable.
5. Field Power: 24-V ac or 24- to 30-V dc.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force, or by oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- B. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.

3.3 CONNECTIONS

- A. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for electrical power connections.

3.4 INSTALLATION

- A. Mount switches not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.

3.5 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification and on face of ceiling directly below instruments concealed above ceilings.

3.6 CHECKOUT PROCEDURES

- A. Check installed products before continuity tests and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation for applicable considerations that impact performance.

3.7 DEMONSTRATION

- A. Train Owner's maintenance personnel to adjust, operate, and maintain instrumentation and control devices.
- B. Coordinate video with operation and maintenance manuals and classroom instruction for use by Owner in operating, maintaining, and troubleshooting.
- C. Record videos on DVD disks.
- D. Owner shall have right to make additional copies of video for internal use without paying royalties.

END OF SECTION 230923.18

SECTION 230923.19 - MOISTURE INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes moisture switches, sensors, and transmitters.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.19.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 2. Product description with complete technical data, performance curves, and product specification sheets.
- B. Shop Drawings:
 - 1. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: To include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 MOISTURE SWITCHES

A. Humidistat for Duct Applications:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Schneider Electric USA, Inc.
2. Description:
 - a. Two-position control.
 - b. Field-adjustable set point.
 - c. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. Performance:
 - a. Relative Humidity Range: 15 to 95 percent.
 - b. Relative Humidity Differential: 5 percent.
 - c. Ambient Temperature: 40 to 135 deg F.
 - d. Voltage: 120-V ac.
 - e. Current: 7.2 FLA.
 - f. Switch Type: SPDT snap switch.
4. Construction:
 - a. Enclosure: Metal, NEMA 250, Type 1.
 - b. Electrical Connections: Screw terminals.

2.2 MOISTURE SENSORS AND TRANSMITTERS

A. Sensors and Transmitters with Digital Display:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Vaisala.
2. Performance:
 - a. Accuracy including non-linearity, hysteresis, and repeatability: Within 2 percent from zero to 90 percent relative humidity and within 2.5 percent from 90 to 100 percent relative humidity when operating between 60 to 77 deg F.
 - b. Relative Humidity Range: Zero to 100 percent.
 - c. Factory calibrated and NIST traceable with certificate included.
3. Construction:
 - a. Provide housing with integral sensor for room applications.

- b. Provide housing with remote sensor probe for ducted applications.
 - 1) Duct Sensor Body: 300 series stainless steel or chrome-plated aluminum, at least 2 inches long for duct-mounted applications.
 - 2) Provide sensor with cable for field installation in conduit.
 - 3) For duct-mounted applications, thread the sensor assembly for connection to a threaded mounting flange.
 - c. Provide general-purpose humidity sensor unless application requires special requirements. Provide sensor with sintered stainless-steel filter for duct applications.
 - d. Housing shall be ABS/PC plastic or powder-coated aluminum.
 - e. Housing Classification: NEMA 250, Type 4 or 4X.
 - f. Provide housing with wall-mounting plate.
- 4. Output Signal: 2-wire, 4- to 20-mA output signal with a drive capacity of at least 500 ohms at 24-V dc.
 - 5. Provide unit with a digital display of relative humidity in percent.
 - 6. Capability for replaceable element. The transmitter shall include noninteracting zero and span adjustments with an output error not exceeding 0.1% of calibrated span. Saturation shall not alter calibration. Sensors for space humidity shall have same appearance as space temperature sensors.

B. Sensor and Transmitter without Display:

- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Vaisala.
- 2. Performance:
 - a. Accuracy including non-linearity, hysteresis, and repeatability: Within 2 percent from zero to 90 percent relative humidity and within 3 percent from 90 to 95 percent relative humidity when operating at 68 deg F.
 - b. Relative Humidity Range:
 - 1) Duct: Zero to 100 percent.
 - 2) Space: Zero to 95 percent relative.
 - c. Factory calibrated and NIST traceable with certificate included.
- 3. Construction for Space Applications:
 - a. Housing with integral sensor.
 - b. Housing shall be ABS plastic or powder-coated aluminum.
 - c. Enclosure: NEMA 250, Type 4.
 - d. Provide housing with a wall-mounting plate.
- 4. Construction for Duct and Equipment Applications:
 - a. Housing with integral sensor.
 - b. Duct Sensor Body: 300 series stainless steel.
 - c. Provide sensor with sintered stainless-steel filter for duct applications.
 - d. Housing shall be cast aluminum.
 - e. Enclosure: NEMA 250, Type 4.

5. Output Signal: Two-wire, 4- to 20-mA output signal with drive capacity of at least 500 ohms at 24-V dc.

C. Combination Humidity and Temperature Sensor and Transmitter with Display:

1. Manufacturers: Subject to compliance with requirements, undefined:
 - a. Vaisala.
2. Description:
 - a. Factory package consisting of humidity and temperature sensor, digital display, keypad user interface, installation hardware, interconnecting sensor cabling, installation instructions, and operating manual.
 - b. Each transmitter shall be individually calibrated and provided with NIST traceable calibration certifications.
 - c. Provide a service cable for connecting to a notebook computer and Microsoft Windows compatible software.
3. Display:
 - a. Alphanumeric display of the following on the face of the enclosure:
 - 1) Percent relative humidity.
 - 2) Absolute humidity.
 - 3) Mixing ratio.
 - 4) Dry-bulb temperature.
 - 5) Wet-bulb temperature.
 - 6) Dew point temperature.
 - 7) Enthalpy.
 - b. Visual display of measurement trends, and minimum and maximum values over a one-year period.
4. Electronics Enclosure:
 - a. Integral to sensors for wall- (room-)mounted applications and remote from temperature and humidity sensors for duct and equipment applications.
 - b. NEMA 250, Type 4 or 4X.
 - c. Labeled terminal strip for field wiring connections.
 - d. 1/2-inch trade size threaded conduit connection.
5. Programming:
 - a. Transmitter parameters shall be field programmable through keypad on the face of the enclosure.
 - b. Programmed parameters shall be stored in nonvolatile EEPROM.
6. Output Signals:
 - a. Three Analog Outputs: 4 to 20 mA or zero to 10-V dc for each output. Option to use a serial communication interface.

7. Temperature Sensor:
 - a. Temperature range matched to application, but not less than minus 40 to 140 deg F.
 - b. Within 0.5 deg F accuracy over the temperature range of 50 to 100 deg F and within 1 deg F over the remainder of the range.
 - c. Provide duct installation kit for duct applications.
8. Humidity Sensor:
 - a. Relative Humidity Measurement Range: Zero to 100 percent.
 - b. Response time in still air within 40 seconds.
 - c. Accuracy including non-linearity, hysteresis, and repeatability:
 - 1) For Temperature Between 59 and 77 Deg F and Relative Humidity between Zero and 90 Percent: Within 1 percent.
 - 2) For Temperature between 59 and 77 Deg F and Relative Humidity between 90 and 100 Percent: Within 1.7 percent.
 - 3) For Temperature between Minus 4 and 104 Deg F: Within 1 percent plus 0.008 times relative humidity reading.
 - 4) For Temperature between Minus 40 and 356 Deg F: Within 1.5 percent plus 0.015 times the relative humidity reading.
 - d. Sintered, stainless-steel filter, protecting sensor.
 - e. Provide duct installation kit for duct applications.
9. Power Supply:
 - a. Field Power: 120-V ac, 60 Hz unless otherwise required by the application.
 - b. Internal Power: As required by transmitter.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Fastening Hardware:
 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.

2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- C. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- D. Corrosive Environments:
1. Use products that are suitable for environment to which they are subjected.
 2. If possible, avoid or limit use of materials in corrosive environments.
 3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
 4. Where instruments are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 MOISTURE INSTRUMENTS INSTALLATION

- A. Mounting Location: Rough-in instrument-mounting locations before setting instruments and routing, cable, wiring, tubing, and conduit to final location.
- B. Mounting Height:
1. Mount instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
 2. Mount switches and transmitters located in mechanical equipment rooms and other similar space not subject to code, state, and Federal accessibility requirements within a range of 42 to 72 inches above the adjacent floor, grade, or service catwalk or platform.
 - a. Make every effort to mount at 60 inches.

3.5 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification on face of ceiling directly below instruments concealed above ceilings.

3.6 CHECKOUT PROCEDURES

- A. Check installed products before continuity tests and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that impact performance.

3.7 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 - 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 - 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
 - 3. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
 - 4. Equipment and procedures used for calibration shall meet instrument manufacturer's written instructions.
 - 5. Provide diagnostic and test equipment for calibration and adjustment.
 - 6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
 - 7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
 - 8. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
 - 9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.
- B. Analog Signals:
 - 1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
 - 2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
 - 3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistance source.
- C. Digital Signals:
 - 1. Check digital signals using a jumper wire.
 - 2. Check digital signals using an ohmmeter to test for contact.
- D. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.
- E. Switches: Calibrate switches to make or break contact at set points indicated.

F. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

END OF SECTION 230923.19

SECTION 230923.21 - MOTION INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. PIR motion sensors.
 - 2. Ultrasonic motion sensors.
 - 3. Dual-technology motion sensors.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.21.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include operating characteristics; electrical characteristics; and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 2. Include product description with complete technical data, performance curves, and product specification sheets.
- B. Shop Drawings:
 - 1. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Product installation location shown in relationship to visual range and obstructions.
 - 2. Wall- and ceiling-mounted instruments located in finished space showing relationship to other installed devices.
- B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For motion instruments to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 INDOOR MOTION SENSORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Hubbell Building Automation, Inc.
 - 2. Leviton Manufacturing Co., Inc.
 - 3. Lutron Electronics Co., Inc.
 - 4. WattStopper; a Legrand® Group brand.
- B. Description: Wall- or ceiling-mounted, solid-state units with a separate relay unit.
 - 1. Operation: Unless otherwise indicated, turn on when covered area is occupied and off when unoccupied; with a time delay for turning off, adjustable over a minimum range of 1 to 15 minutes.
 - 2. Sensor Output: Contacts rated to operate the connected relay, complying with UL 773A. Sensor shall be powered from the relay unit.
 - 3. Relay Unit: Dry contacts rated for 20-A load at 120- and 277-V ac. Power supply to sensor shall be 24-V dc, 150 mA, Class 2 power source as defined by NFPA 70.
 - 4. Mounting:
 - a. Sensor: Suitable for mounting in any position on a standard outlet box.
 - b. Relay: Externally mounted through a 1/2-inch knock out in a standard electrical enclosure.
 - c. Time-Delay and Sensitivity Adjustments: Recessed and concealed behind hinged door.
 - 5. Indicator: Digital display, to show when motion is being detected during testing and normal operation of the sensor.
 - 6. Bypass Switch: Override the on function in case of sensor failure.
- C. PIR Type: Ceiling mounting; detect occupancy by sensing a combination of heat and movement in coverage area.
 - 1. Detector Sensitivity: Detect occurrences of 6-inch- minimum movement of any portion of a human body that presents a target of not less than 36 sq. in.
 - 2. Detection Coverage (Room): Detect occupancy anywhere in a circular area of 1000 sq. ft. when mounted on a 96-inch- high ceiling.

3. Detection Coverage (Corridor): Detect occupancy within 90 feet when mounted on a 10-foot- high ceiling.
- D. Ultrasonic Type: Ceiling mounting; detect occupancy by sensing a change in pattern of reflected ultrasonic energy in coverage area.
 1. Detector Sensitivity: Detect a person of average size and weight moving not less than 12 inches in either a horizontal or a vertical manner at an approximate speed of 12 inches/s.
 2. Detection Coverage (Small Room): Detect occupancy anywhere within a circular area of 600 sq. ft. when mounted on a 96-inch- high ceiling.
 3. Detection Coverage (Standard Room): Detect occupancy anywhere within a circular area of 1000 sq. ft. when mounted on a 96-inch- high ceiling.
 4. Detection Coverage (Large Room): Detect occupancy anywhere within a circular area of 2000 sq. ft. when mounted on a 96-inch- high ceiling.
 5. Detection Coverage (Corridor): Detect occupancy anywhere within 90 feet when mounted on a 10-foot- high ceiling in a corridor not wider than 14 feet.
- E. Dual-Technology Type: Ceiling mounting; detect occupancy by using a combination of PIR and ultrasonic detection methods in coverage area. A particular technology or combination of technologies that controls on-off functions shall be field selectable by operating controls on unit.
 1. Sensitivity Adjustment: Separate for each sensing technology.
 2. Detector Sensitivity: Detect occurrences of 6-inch- minimum movement of any portion of a human body that presents a target of not less than 36 sq. in., and detect a person of average size and weight moving not less than 12 inches in either a horizontal or a vertical manner at an approximate speed of 12 inches/s.
 3. Detection Coverage (Standard Room): Detect occupancy anywhere within a circular area of 1000 sq. ft. when mounted on a 96-inch- high ceiling. Apply occupancy detectors where indicated.

2.2 SWITCHBOX-MOUNTED MOTION SENSORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Hubbell Building Automation, Inc.
 2. Leviton Manufacturing Co., Inc.
 3. Lutron Electronics Co., Inc.
 4. WattStopper; a Legrand® Group brand.
- B. General Requirements for Sensors: Automatic-wall-switch occupancy sensor, suitable for mounting in a single gang switchbox.
 1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Operating Ambient Conditions: Dry interior conditions, 32 to 120 deg F.
 3. Switch Rating: Not less than 800-VA fluorescent at 120 V, 1200-VA fluorescent at 277 V, and 800-W incandescent.
- C. Wall-Switch Sensor Tag WS1:
 1. Standard Range: 180-degree field of view, field adjustable from 180 to 40 degrees; with a minimum coverage area of 900 sq. ft..
 2. Sensing Technology: Dual technology - PIR and ultrasonic.

3. Ambient-Light Override: Concealed, field-adjustable, light-level sensor from 10 to 150 fc. The switch prevents the lights from turning on when the light level is higher than the set point of the sensor.
 4. Concealed, field-adjustable, "off" time-delay selector at up to 30 minutes.
 5. Adaptive Technology: Self-adjusting circuitry detects and memorizes usage patterns of the space and helps eliminate false "off" switching.
- D. Wall-Switch Sensor Tag WS2:
1. Standard Range: 210-degree field of view, with a minimum coverage area of 900 sq. ft..
 2. Sensing Technology: PIR.
 3. Ambient-Light Override: Concealed, field-adjustable, light-level sensor from 10 to 150 fc. The switch prevents the lights from turning on when the light level is higher than the set point of the sensor.
 4. Concealed, field-adjustable, "off" time-delay selector at up to 30 minutes.
 5. Adaptive Technology: Self-adjusting circuitry detects and memorizes usage patterns of the space and helps eliminate false "off" switching.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 SENSOR INSTALLATION

- A. Coordinate layout and installation of ceiling-mounted devices with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, smoke detectors, fire-suppression systems, and partition assemblies.
- B. Coordinate layout and installation of wall-mounted devices with other wall-mounted devices. Align centerline with adjacent devices. Align centerline with devices above.
- C. Install and aim sensors in locations to achieve not less than 90 percent coverage of areas indicated. Do not exceed coverage limits specified in manufacturer's written instructions.

3.3 ELECTRICAL POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to evaluate lighting control devices and perform tests and inspections.
- B. Motion instruments will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

3.6 DEMONSTRATION

- A. Coordinate demonstration of products specified in this Section with demonstration requirements for direct-digital control systems specified in Section 230923 "Direct-Digital Control System for HVAC."
- B. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain lighting control devices.

END OF SECTION 230923.21

SECTION 230923.22 - POSITION INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes position limit switches for use in direct-digital control systems for HVAC.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.22.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include operating characteristics, electrical characteristics, and furnished accessories indicating default control signal with loss of power and electrical power requirements.
 - 2. Include product description with complete technical data and product specification sheets.
- B. Shop Drawings:
 - 1. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Include diagrams for power, signal, and control wiring.
 - 3. Include number-coded identification system for unique identification of wiring.

PART 2 - PRODUCTS

2.1 POSITION LIMIT SWITCHES

- A. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - 1. OMRON Corporation.
- B. Description: Select type of actuating head (plunger, roller lever, or rod) to suit application.
 - 1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Performance:

1. Life expectancy: Not less than 30 million mechanical operations and 750,000 electrical operations.
2. Operating Frequency: 300 mechanical operations per minute and 30 electrical operations per minute.
3. Voltage: 125-, 250-, 480-, and 600-V ac or 8-, 12-, 14-, 24-, 30-, 48-, 125-, and 250-V dc, as required by application.
4. Current Rating: As required by application.
5. Temperature Rise: 50 deg C.
6. Ambient Temperature: 14 to 175 deg F.
7. Ambient Relative Humidity: 35 to 95 percent.

D. Construction:

1. NEMA 250, Type 4X enclosure.
2. Switch Type: SPDT or DPDT, as required by application.
3. Status indicator integral to switch. Field switchable to light when contacts are actuated and operating, or contacts are free and not operating.
4. Electrical Connection: Screw or plug-in terminals.
5. Conduit Connection: NPS 1/2.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Fastening Hardware:
 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by using excessive force or oversized wrenches.
 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- C. Install products in locations that are accessible and that permit maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.

3.3 ELECTRICAL POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 POSITION INSTRUMENTS INSTALLATION

- A. Mounting Location:
 - 1. Rough-in instrument-mounting locations before setting instruments and routing, cable, wiring, and conduit to final location.
 - 2. Use manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
- B. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated, using neoprene gaskets or grommets.

3.5 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Digital Signals:
 - 1. Check digital signals using a jumper wire.
 - 2. Check digital signals using an ohmmeter to test for contact.
- B. Switches: Calibrate switches to make or break contact at set points indicated.

END OF SECTION 230923.22

SECTION 230923.23 - PRESSURE INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Air-pressure sensors.
 - 2. Air-pressure switches.
 - 3. Air-pressure transmitters.
 - 4. Liquid-pressure switches.
 - 5. Liquid-pressure transmitters.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.23.

1.3 DEFINITIONS

- A. HART: Highway addressable remote transducer protocol is the global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring systems through bi-directional communication that provides data access between intelligent field instruments and host systems. A host can be any software application from technician's hand-held device or laptop to a control, asset management, safety, or other system using any control platform.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics; electrical characteristics; and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 3. Product description with complete technical data, performance curves, and product specification sheets.
 - 4. Installation instructions, including factors affecting performance.

B. Shop Drawings:

1. Include plans, elevations, sections, and mounting details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.5 INFORMATIONAL SUBMITTALS

- A. Product Certificates: For each product requiring a certificate.
- B. Source quality-control reports.
- C. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For instruments to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Environmental Conditions:

1. Instruments shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
 - a. If instrument alone cannot comply with requirement, install instrument in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, filtered, and ventilated as required by instrument and application.
2. Instruments and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Instrument-installed location shall dictate following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: Type 2.
 - b. Outdoors, Unprotected: Type 4X.
 - c. Indoors, Heated with Filtered Ventilation: Type 1.
 - d. Indoors, Heated with Nonfiltered Ventilation: Type 2.
 - e. Indoors, Heated and Air-Conditioned: Type 1.
 - f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: Type 12.
 - 2) Air-Moving Equipment Rooms: Type 1.
 - g. Localized Areas Exposed to Washdown: Type 4X.

- h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 2.
- i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: Type 4X.

2.2 AIR-PRESSURE SENSORS

A. Duct Insertion Static Pressure Sensor:

1. 2-wire strain gauge type, designed for media sensed for static pressure or differential pressure. The span shall be continuously adjustable from 0% to 125% of the expected full pressure or full flow differential pressure. The zero shall be continuously adjustable on outputs. Transmitters shall produce a 4-20 mA signal with an accuracy of $\pm 1.0\%$ of the upper range limit for 6 months from calibration. Instruments shall be capable of withstanding an overrange pressure limit of 300% normal.
2. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. MAMAC Systems, Inc.
3. Sensor probe with two opposing orifices designed to reduce error-associated air velocity.
4. Sensor insertion length shall be 8 inches.
5. Construct sensor of 6061-T6 aluminum alloy or Type 304 stainless steel.
6. Connection: Threaded, NPS 1/8 swivel fitting for connection to copper tubing or NPS 1/4 barbed fitting for connection to polyethylene tubing.
7. Sensor probe attached to a mounting flange with neoprene gasket and two holes for fasteners.
8. Mounting flange shall be suitable for flat oval, rectangular, and round duct configurations.
9. Pressure Rating: 10 psig.

B. Duct Traverse Static Pressure Sensor:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Air Monitor Corporation.
2. Sensor probe with two opposing orifices designed to reduce error-associated air velocity.
3. Sensor shall traverse the duct cross section and have at least one pickup point every 6 inches along length of sensor.
4. Construct sensor of 18-gage Type T6063-T5 extruded and anodized aluminum.
5. Sensor supported with threaded rod, sealing washer, and nut at one end and a mounting plate with gasket at other end.
6. Mounting plate with threaded, NPS 3/8 compression fitting for connection to tubing.
7. Accuracy within 1 percent of actual operating static pressure.
8. Dual offset static sensor design shall provide accurate sensing of duct static pressure in the presence of turbulent and rotational airflows with a maximum 30 degree yaw and pitch.
9. Suitable for velocities of 100 to 10000 fpm and temperatures of up to 200 deg F.
10. Sensor air resistance shall be less than 0.1 times the velocity pressure at probe-operating velocity.
11. Suitable for flat oval, rectangular, and round duct configurations.

C. Outdoor Static Pressure Sensor:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Air Monitor Corporation.

2. Sensor with no moving parts.
3. Operation not affected and impaired by rain and snow.
4. Sensing plates constructed of 0.1406-inch Type 316 stainless steel.
5. Accuracy within:
 - a. 1 percent of the actual outdoor atmospheric pressure when subjected to varying horizontal radial wind velocities up to 40 mph.
 - b. 2 percent of the actual outdoor atmospheric pressure while subjected to varying radial wind velocities up to 40 mph with approach angles up to 30 degrees to horizontal.
 - c. 3 percent of the actual outdoor atmospheric pressure while subjected to varying radial wind velocities up to 40 mph with approach angles up to 60 degrees to horizontal.
 - d. Threaded, NPS 2 connection.

D. Space Static Pressure Sensor for Wall Mounting:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Air Monitor Corporation.
2. Stainless-steel wall plate with perforated center arranged to sense space static pressure. Exposed surfaces are provided with brush finish.
3. Wall plate provided with screws and sized to fit standard single-gang electrical box.
4. Back of sensor plate fitted with multiple sensing ports, pressure impulse suppression chamber, airflow shielding, and 0.125-inch fitting for tubing connection.
5. Performance: Within 1 percent of actual room static pressure in vicinity of sensor while being subjected to an air velocity of 1000 fpm from a 360-degree radial source.

E. Space Static Pressure Sensor for Recessed Ceiling Mounting:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Air Monitor Corporation.
2. Stainless-steel round plate with perforated center arranged to sense space static pressure. Exposed surfaces provided with brush finish.
3. Sensor intended for flush mount on face of ceiling with pressure chamber recessed in ceiling plenum.
4. Back of sensor plate fitted with multiple sensing ports, pressure impulse suppression chamber, airflow shielding, and 0.125-inch fitting for concealed tubing connection.
5. Performance: Within 1 percent of actual room static pressure in vicinity of sensor while being subjected to an air velocity of 1000 fpm from a 360-degree radial source.

F. Space Static Pressure Sensor for Exposed or Suspended Mounting:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Air Monitor Corporation.
2. Performance: Within 1 percent of actual room static pressure in vicinity of sensor while being subjected to an air velocity of 1000 fpm from a 360-degree radial source.
3. Stainless steel with perforations arranged to sense space static pressure. Exposed surfaces provided with brush finish.
4. Sensor fitted with multiple sensing ports, pressure impulse suppression chamber, and airflow shielding.

5. Surface-mounted sensor provided with solid mounting plate intended for mount to ceiling with pressure chamber exposed to view.
6. Surface-mounted sensor with 0.125-inch fitting for exposed tubing connection.
7. Suspended sensor intended for pendent mount with pressure chamber exposed to view.
8. Suspended sensor with NPS 1/2 fitting for exposed pipe or tubing connection.

2.3 AIR-PRESSURE SWITCHES

A. Air-Pressure Differential Switch:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Dwyer Instruments, Inc.
2. Diaphragm operated to actuate an SPDT snap switch.
 - a. Fan safety shutdown applications: Switch with manual reset.
3. Electrical Connections: Three-screw configuration, including one screw for common operation and two screws for field-selectable normally open or closed operation.
4. Enclosure Conduit Connection: Knock out or threaded connection.
5. User Interface: Screw-type set-point adjustment located inside removable enclosure cover.
6. High and Low Process Connections: Threaded, NPS 1/8.
7. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 1.
 - b. Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - c. Hazardous Environments: Explosion proof.
8. Operating Data:
 - a. Electrical Rating: 15 A at 120- to 480-V ac.
 - b. Pressure Limits:
 - 1) Continuous: 45 inches wg.
 - 2) Surge: 10 psig.
 - c. Temperature Limits: Minus 30 to 180 deg F.
 - d. Operating Range: Approximately 2 times set point.
 - e. Repeatability: Within 3 percent.
 - f. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Air-Pressure Differential Switch with Set-Point Indicator:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Dwyer Instruments, Inc.
2. Diaphragm operated to actuate an SPDT snap switch.
3. Electrical Connections: Three-screw configuration, including one screw for common operation and two screws for field-selectable normally open or closed operation.
4. Enclosure Conduit Connection: Knock out or threaded connection.
5. User Interface: Screw-type set-point adjustment with enclosed set-point indicator and scale.

6. High and Low Process Connections: Threaded, NPS 1/8.
7. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 1.
 - b. Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - c. Hazardous Environments: Explosion proof.
8. Operating Data:
 - a. Electrical Rating: 15 A at 120- to 480-V ac.
 - b. Pressure Limits:
 - 1) Continuous: 10 psig.
 - 2) Surge: 25 psig.
 - c. Temperature Limits: Minus 30 to 110 deg F.
 - d. Operating Range: Approximately 2 times set point.
 - e. Repeatability: Within 1 percent.
 - f. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Air-Pressure Differential Switch with Dual Scale Adjustable Set Point:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Dwyer Instruments, Inc.
2. Diaphragm operated to actuate an SPDT snap switch.
3. Electrical Connections: Push-on screw terminals.
4. Enclosure Conduit Connection: Knock out or threaded connection.
5. User Interface: Dual scale set-point adjustment knob located inside removable enclosure cover.
6. High and Low Process Connections: Slip-on tubing connections.
7. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 13.
8. Operating Data:
 - a. Electrical Rating: 1.5 A at 250-V ac.
 - b. Pressure Limits: 40 inches wg
 - c. Temperature Limits: Minus 4 to 185 deg F.
 - d. Operating Range: Approximately 2 times set point.

D. Air-Pressure Differential Indicating Switch:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Dwyer Instruments, Inc.
2. Combination gage with low- and high-limit switches.
3. Nominal 4-inch- diameter analog indication with white dial face, graduated black markings, pointer to indicate measured value, and a separate adjustable pointer for each switch set point.
4. Switch zero and set-point adjustment screws or knobs on the dial face.
5. Each switch used as a safety limit shall have a manual reset button local to switch.
6. Switch Type: Each set point shall have two Form C relays, DPDT.

7. Electrical Connections: Screw terminals.
8. Enclosure Conduit Connection: NPS 3/4 threaded connection.
9. High and Low Process Connections: Threaded, NPS 1/8.
10. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 1.
 - b. Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - c. Hazardous Environments: Explosion proof.
11. Operating Data:
 - a. Electrical Rating: 10 A at 120- to 240-V ac.
 - b. Pressure Limits: 25 psig.
 - c. Temperature Limits: 20 to 120 deg F.
 - d. Operating Range: Approximately twice normal operating range unless otherwise required for application.
 - e. Accuracy:
 - 1) 4 percent for ranges through 0.5 in. wg.
 - 2) 2 percent for ranges 1 in. wg and greater.
 - f. Repeatability: Within 1 percent of full scale.
 - g. Switch Deadband: One pointer width and within 1 percent of full scale for each switch set point.
 - h. Power Supply: 24 -V ac, 50/60 Hz.
 - i. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.4 AIR-PRESSURE TRANSMITTERS

A. Air Pressure Differential Transmitter:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Ashcroft Inc.
2. Performance:
 - a. Range: Approximately 2 times set point.
 - b. Accuracy: Within 0.25 percent of the span at reference temperature of 70 deg F.
 - c. Hysteresis: Within 0.02 percent of the span.
 - d. Repeatability: Within 0.05 percent of the calibrated span.
 - e. Stability: Within 0.25 percent of span per year.
 - f. Overpressure: 15 psig.
 - g. Temperature Limits: Minus 20 to 160 deg F.
 - h. Compensate Temperature Limits: 35 to 135 deg F.
 - i. Thermal Effects: 0.015 percent of full scale per degree F.
 - j. Warm-up Time: Within 5 seconds.
 - k. Response Time: 5 ms.
 - l. Shock and vibration shall not harm the transmitter.

3. Output Signals:
 - a. Analog Current Signal:
 - 1) Two-wire, 4- to 20-mA dc current source.
 - 2) Signal capable of operating into 1000-ohm load.
 - b. Analog Voltage Signal:
 - 1) Three wire, zero to 5 V.
 - 2) Minimum Load Resistance: 1000 ohms.
4. Operator Interface:
 - a. Zero and span adjustments within 10 percent of full span.
 - b. Potentiometer adjustments located on face of transmitter.
5. Construction:
 - a. Type 300 stainless-steel enclosure.
 - b. Swivel fittings for connection to copper tubing or barbed fittings for connection to polyethylene tubing. Fittings on front of instrument enclosure.
 - c. Screw terminal block for wire connections.
 - d. Vertical plane mounting.
 - e. NEMA 250, Type 2.
 - f. Mounting Bracket: Appropriate for installation.
 - g. Reverse wiring protected.
 - h. Calibrate to NIST-traceable standards and provide each transmitter with a certificate of calibration.

B. Air-Pressure Differential Indicating Transmitter:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Dwyer Instruments, Inc.
2. Performance:
 - a. Range: Approximately 2 times set point.
 - b. Accuracy Including Hysteresis and Repeatability: Within 1 percent of full scale at 77 deg F.
 - c. Stability: Within 1 percent of full scale per year.
 - d. Overpressure: 10 psig.
 - e. Temperature Limits: 20 to 120 deg F.
 - f. Thermal Effects: 0.055 percent of full scale per degree F.
3. Display: Four-digit digital display with minimum 0.4-inch-high numeric characters.
4. Operator Interface:
 - a. Zero and span adjustments.
 - b. Selectable engineering units.
5. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into a 1200-ohm load.

6. Construction:
 - a. Plastic casing with clear plastic cover.
 - b. Integral fittings for plastic tubing connections on side of instrument case for high- and low-pressure connections.
 - c. Terminal block for wire connections.
 - d. Vertical plane mounting.
 - e. NEMA 250, Type 1.
 - f. Nominal 4-inch diameter face.
 - g. Mounting Bracket: Appropriate for installation.

C. Air-Pressure Differential Indicating Transmitter with Field-Selectable Features:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Dwyer Instruments, Inc.
2. Field-Selectable Features:
 - a. Field configurable for pressure and velocity applications through user interface.
 - b. Field selectable from one of three pressure ranges both in SI (metric) and inch-pound (IP) units of measure.
 - c. Select range based on application. Range shall be approximately 2 times set point.
3. Performance:
 - a. Accuracy Including Hysteresis and Repeatability:
 - 1) Within 2 percent for 0.10 in. wg, 1.0 in. wg and all bi-directional ranges.
 - 2) Within 1 percent for other ranges.
 - b. Stability: Within 1 percent of full scale per year.
 - c. Response Time: Adjustable 0.5- to 15-second time constant with 95 percent response within 1.5 to 45 seconds.
 - d. Overpressure: 1 psig maximum operating; 10 psig burst pressure.
 - e. Temperature Limits: Zero to 150 deg F.
4. Display: Four-digit digital display with minimum 0.4-inch- high numeric characters.
5. Operator Interface:
 - a. Selectable pressure ranges, where indicated.
 - b. Zero and span adjustments.
 - c. Selectable air velocity mode with square root function.
 - d. Adjustable signal dampening
6. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into a 1200-ohm load.
7. Analog Output Voltage Signal:
 - a. Three wire, zero to 10 V.
 - b. Minimum Load Resistance: 1000 ohms.

8. Construction:
 - a. Plastic casing with removable clear plastic cover.
 - b. NPS 3/16 nominal ID plastic tubing connections on side of instrument case for high- and low-pressure connections.
 - c. NPS 1/2 NPS threaded connection for conduit.
 - d. Terminal block for wire connections.
 - e. Vertical plane mounting.
 - f. NEMA 250, Type 4X.
 - g. Nominal 4-inch- diameter face.
 - h. Mounting Bracket: Appropriate for installation.

D. Air-Pressure Differential Transmitter with 0.10 Percent Accuracy and Auto Zero Feature:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Air Monitor Corporation.
2. Description:
 - a. 4- to 20-mA dc output signal.
 - b. NEMA 250, Type 1 enclosure.
 - c. Construct the assembly so that shock, vibration, and pressure surges of up to 1 psig will neither harm nor affect the accuracy of the transmitter.
 - d. Transmitter with automatic zeroing circuit capable of automatically readjusting the transmitter to zero at predetermined time intervals. The automatic zeroing circuit shall re-zero the transmitter to within 0.1 percent of true zero.
 - e. Performance:
 - 1) Range: Approximately 2 times set point.
 - 2) Calibrated Span: Field adjustable, minus 40 percent of the range.
 - 3) Accuracy: Within 0.10 percent of natural span.
 - 4) Repeatability: Within 0.15 percent of calibrated span.
 - 5) Linearity: Within 0.2 percent of calibrated span.
 - 6) Hysteresis and deadband (combined): Less than 0.2 percent of calibrated span.
 - f. Integral digital display for continuous indication of pressure differential.

E. Air-Pressure Differential Transmitter with 0.25 Percent Accuracy and Auto Zero Feature:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Air Monitor Corporation.
2. Description:
 - a. 4- to 20-mA dc output signal.
 - b. NEMA 250, Type 1 enclosure.
 - c. Construct assembly so shock, vibration, and pressure surges of up to 1 psig will neither harm nor affect the accuracy of the transmitter.
 - d. Transmitter with automatic zeroing circuit capable of automatically readjusting the transmitter to zero at predetermined time intervals. The automatic zeroing circuit shall re-zero transmitter to within 0.1 percent of true zero.
 - e. Performance:

- 1) Range: As required by application and at least 10 percent below minimum airflow and 10 percent greater than design airflow.
 - 2) Calibrated Span: Field adjustable, minus 40 percent of the range.
 - 3) Accuracy: Within 0.25 percent of natural span.
 - 4) Repeatability: Within 0.15 percent of calibrated span.
 - 5) Linearity: Within 0.2 percent of calibrated span.
 - 6) Hysteresis and deadband (combined): Less than 0.2 percent of calibrated span.
 - f. Integral digital display for continuous indication of pressure differential.
- F. Air-Pressure Differential Indicating Transmitter, Switch, and Controller:
 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Dwyer Instruments, Inc.
 2. Description:
 - a. Three-in-one instrument, including digital display, control relay switches, and a transmitter with a current output.
 - b. Field configurable for pressure, velocity, and volumetric flow applications through user interface.
 - c. Select instrument range based on application. Range shall be approximately 2 times set point.
 3. Performance:
 - a. Accuracy Including Hysteresis and Repeatability:
 - 1) Within 1 percent for ranges less than 5 in. wg.
 - 2) Within 0.5 percent at 77 deg F for other ranges.
 - b. Stability: Within 1 percent per year.
 - c. Response Time: 250 ms.
 - d. Overpressure: 5 psig for instrument ranges less than 50 in wg and 9 psig for 100 in. wg range.
 - e. Temperature Limits: 32 to 140 deg F.
 - f. Thermal Effects: 0.020 percent per degree F.
 - g. Warm-up Period: One hour.
 4. Controller Programming through Menu Keys to Access Five Menus:
 - a. Security level.
 - b. Pressure, velocity, or flow application.
 - c. Engineering units.
 - d. K-factor for use with flow application.
 - e. Set-point control only; set-point and alarm operation; and alarm operation as high, low, or high/low with manual or automatic reset and delay.
 - f. View high and low readings.
 - g. Digital dampening for smoothing erratic applications.
 - h. Scaling of analog output to fit range and field calibration.
 5. Display:
 - a. Digital, four-digit display with backlight, with 0.4-inch- high alphanumeric characters.
 - b. Four indicators; two for set point and two for alarm status.

6. Operator Interface:
 - a. Set-point adjustment through keypad on face of instrument.
 - b. Zero and span adjustments accessible through menu.
 - c. Programming through keypad.
7. Analog Output Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into a 900-ohm load.
8. Digital Output Signal:
 - a. Two SPDT relays.
 - b. Each rated for one amp at 30-V ac or dc.
9. Construction:
 - a. Die cast-aluminum casing and bezel.
 - b. Threaded, NPS 1/8 connections on side and back.
 - c. Vertical plane mounting.
 - d. NEMA 250, Type 1.
 - e. Nominal 4-inch- diameter face.
 - f. Mounting Bracket: Appropriate for installation.

2.5 LIQUID-PRESSURE SWITCHES

A. Liquid Gage Pressure Switch, Diaphragm Operated, Low Pressure:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Mercoid Controls: Dwyer Instruments, Inc.
2. Description:
 - a. Diaphragm operated to actuate an SPDT snap switch.
 - b. Electrical Connections: Screw terminal.
 - c. Enclosure Conduit Connection: Knock out or threaded connection.
 - d. User Interface: External screw with visual set-point adjustment.
 - e. Process Connection: Threaded, NPS 1/4.
 - f. Enclosure:
 - 1) Dry Indoor Installations: NEMA 250, Type 1.
 - 2) Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
 - 3) Hazardous Environments: Explosion proof.
3. Operating Data:
 - a. Electrical Rating: 15 A at 120-V ac.
 - b. Pressure Limits:
 - 1) Range 1 to 30 psig: 60 psig.
 - 2) Range 10 to 125 psig: 160 psig.

- c. Temperature Limits: Minus 30 to 150 deg F.
 - d. Operating Range: 1 to 30 psig.
 - e. Deadband: Fixed.
 - 4. Pressure Chamber Material: Stainless steel.
 - 5. Diaphragm Material: PTFE.
- B. Liquid Gage Pressure Switch-Diaphragm Operated:
- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Mercoid Controls: Dwyer Instruments, Inc.
 - 2. Diaphragm operated to actuate a DPDT snap switch.
 - 3. Electrical Connections: Screw terminal.
 - 4. Enclosure Conduit Connection: Knock out or threaded connection.
 - 5. User Interface: Internal hex nut set-point adjustment with enclosed set-point indicator and scale.
 - a. Process Connection: Threaded, NPS 1/4 or NPS 1/2.
 - 6. Enclosure:
 - a. Dry Indoor Installations: NEMA 250, Type 1, 12.
 - b. Outdoor and Wet Indoor Installations: NEMA 250, Type 4X.
 - c. Hazardous Environments: Explosion proof.
 - 7. Operating Data:
 - a. Electrical Rating: 15 A at 120-, 240-, and 480-V ac.
 - b. Pressure Limits: 1200 psig.
 - c. Ambient Temperature Limits: Minus 30 to 180 deg F.
 - d. Process Temperature Limits: Minus 4 to 167 deg F.
 - e. Adjustable Operating Range: 10 to 150 psig.
 - f. Deadband: Adjustable.
 - 8. Pressure Chamber Material: Aluminum or brass or stainless steel.
 - 9. Diaphragm Material: Buna-N or fluorocarbon.
- C. Liquid Gage Pressure Switch-Bourdon Tube Operated:
- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Dwyer Instruments, Inc.
 - 2. Description:
 - a. Bourdon tube operated to actuate a DPDT snap switch.
 - b. Provide switches used in safety limiting applications with manual reset.
 - c. Wetted Materials: Type 316 stainless steel.
 - d. Electrical Connections: Screw terminal.
 - e. Enclosure Conduit Connection: Knock out or threaded connection.
 - f. User Interface: Thumbscrew set-point adjustment with enclosed set-point indicator and scale.
 - g. Process Connection: Threaded, NPS 1/4.
 - h. Enclosure:

- 1) Dry Indoor Installations: NEMA 250, Type 1.
- 2) Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
- 3) Hazardous Environments: Explosion proof.

i. Operating Data:

- 1) Electrical Rating: 10 A at 120-V ac.
- 2) Pressure Limits: Equal to maximum pressure in full-scale range, but not less than system design pressure rating.
- 3) Temperature Limits: 180 deg F.
- 4) Operating Range: Approximately 2 times set point, but not less than system design pressure rating.
- 5) Deadband: Adjustable or fixed as required by application.

j. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

D. Liquid-Pressure Differential Switch with Set-Point Indicator:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

- a. Dwyer Instruments, Inc.

2. Description:

- a. Type 316 stainless-steel double opposing bellows operate to actuate a SPDT snap switch.
- b. Electrical Connections: Screw terminal.
- c. Enclosure Conduit Connection: Knock out or threaded connection.
- d. User Interface: Thumbscrew set-point adjustment with enclosed set-point indicator and scale.
- e. High and Low Process Connections: Threaded, NPS 1/8.
- f. Enclosure:

- 1) Dry Indoor Installations: NEMA 250, Type 1.
- 2) Outdoor and Wet Indoor Installations: NEMA 250, Type 4.
- 3) Hazardous Environments: Explosion proof.

g. Operating Data:

- 1) Electrical Rating: 15 A at 120- to 240-V ac.
- 2) Pressure Limits: At least 5 times full-scale range, but not less than system design pressure rating.
- 3) Temperature Limits: Minus 10 to 180 deg F.
- 4) Operating Range: Approximately 2 times set point.
- 5) Deadband: Adjustable or fixed as required by application.

E. Liquid-Pressure Differential Switch:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:

- a. Ashcroft Inc.

2. Description:

- a. Type 316 stainless-steel double opposing bellows operate to actuate an SPDT snap switch.

- b. Wetted materials: Type 316 stainless steel.
- c. Seal: Buna-N or Viton.
- d. Electrical Connections: Screw terminal.
- e. Enclosure Conduit Connection: Knock out or threaded connection.
- f. User Interface: Thumbscrew set-point adjustment with enclosed set-point indicator and scale.
- g. High and Low Process Connections: Threaded, NPS 1/4.
- h. Enclosure: NEMA 250, Type 4 or 4X.
- i. Operating Data:
 - 1) Electrical Rating: 10 A at 120- to 240-V ac.
 - 2) Pressure Limits: Zero to 500 psig
 - 3) Ambient Temperature Limits: Minus 20 to 150 deg F.
 - 4) Process Temperature Limits: 20 to 300 deg F.
 - 5) Operating Range: 2 times set point, unless otherwise required by application.
 - 6) Deadband: Adjustable or fixed as required by application.
- j. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.6 LIQUID-PRESSURE TRANSMITTERS

A. Liquid Gage Pressure Transmitter with Adjustable Span:

- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Rosemount; Emerson Process Management.
- 2. Hazardous Classification: FM Approved for hazardous environments.
 - a. Intrinsically safe for Classes I, II, and III, Divisions 1 and 2, Groups A through H.
 - b. Explosion proof for Class I, Division 1, Groups B, C, and D.
 - c. Dust ignition proof for Class II, Division 1, Groups E, F, and G.
 - d. Dust ignition proof for Class III, Division 1.
- 3. Performance:
 - a. Range: Minus 300 to 300 psig.
 - b. Span: Field adjustable.
 - c. Minimum Span: 3 psig.
 - d. Reference Accuracy: Within 0.07 percent of span or better.
 - e. Stability: Within 0.125 percent of upper range limit for 5 years.
 - f. Overpressure Limits: 3626 psig.
 - g. Process Temperature Limits: Minus 40 to 250 deg F.
 - h. Ambient Temperature Limits: Minus 40 to 185 deg F.
 - i. Temperature Effect: Within 0.025 percent of upper range limit plus 0.125 percent of span.
 - j. Shock and vibration shall not harm the transmitter.
- 4. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - c. Digital signal based on HART protocol carried with current signal.
 - d. Dampening: Field selectable from zero to 30 seconds.

5. Operator Interface: Zero and span adjustments located behind cover.
6. Display: Digital, five-digit, two-line display with 0.4-inch- high alphanumeric characters.
7. Construction:
 - a. Non-wetted parts of transmitter constructed of aluminum or stainless steel.
 - b. Enclosure with removable cover on each side.
 - c. Wetted parts of transmitter constructed of Type 316 stainless steel.
 - d. Threaded, NPS 1/2 process connection on bottom of instrument.
 - e. Drain/vent valve on process connection.
 - f. Two 1/2-inch trade size conduit connections on side of instrument enclosure.
 - g. Screw terminal block for wire connections.
 - h. NEMA 250, Type 4X.
 - i. Mounting Bracket: Appropriate for installation.

B. Liquid-Pressure Differential Transmitter:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Setra System.
2. Performance:
 - a. Range: Approximately 2 times the set point.
 - b. Span: Adjustable plus or minus one milliamp, noninteractive.
 - c. Accuracy: Within 0.25 percent of full scale.
 - d. Hysteresis: Within 0.1 percent of full scale.
 - e. Repeatability: Within 0.05 percent of full scale.
 - f. Maximum Working Pressure: 250 psig.
 - g. Temperature Limits: Zero to 175 deg F.
 - h. Compensate Temperature Limits: 30 to 150 deg F.
 - i. Thermal Effects: 0.02 percent of full scale per degree F.
 - j. Response Time: 30 to 50 ms.
 - k. Shock and vibration shall not harm the transmitter.
3. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
4. Analog Output Voltage Signal:
 - a. Three wire, zero to 10 V.
 - b. Minimum Load Resistance: 1000 ohms.
5. Operator Interface:
 - a. Zero and span adjustments located behind cover.
 - b. Bleed screws on side of body, two screws on low-pressure side, and one screw on high-pressure side, for air in line and pressure cavity.
6. Construction:
 - a. Aluminum and stainless-steel enclosure with removable cover.
 - b. Wetted parts of transmitter constructed of 17-4 PH or 300 Series stainless steel.
 - c. Threaded, NPS 1/4 process connections on side of instrument enclosure.
 - d. Knock out for 1/2-inch nominal conduit connection on side of instrument enclosure.

- e. Screw terminal block for wire connections.
 - f. NEMA 250, Type 4.
 - g. Mounting Bracket: Appropriate for installation.
 - 7. Provide transmitter with three-valve manifold. Construct manifold of brass, bronze, or stainless steel. Provide manifold with NPS 1/4 NPT process connections.
- C. Liquid-Pressure Differential Transmitter with Field-Selectable Ranges:
- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. MAMAC Systems, Inc.
 - 2. Performance:
 - a. Field-Selectable Ranges:
 - 1) 25, 50, 100 psig.
 - b. Accuracy: Within 1 percent of the full-scale range.
 - c. Static Pressure: 2 times full-scale range.
 - d. Overpressure: Proof pressure 3 times full-scale range, burst pressure 5 times full scale.
 - e. Compensate Temperature Limits: Zero to 180 deg F.
 - f. Thermal Effects: 0.025 percent of full scale per degree F.
 - g. Shock and vibration shall not harm the transmitter.
 - 3. Analog Output Current Signal:
 - a. Two-wire, 4- to 20-mA dc current source.
 - b. Signal capable of operating into 1000-ohm load.
 - 4. Analog Output Voltage Signals:
 - a. Three wire, field selectable from zero to 5 V or zero to 10 V.
 - b. Minimum Load Resistance: 1000 ohms.
 - 5. Operator Interface:
 - a. Zero button located behind cover.
 - b. Range selector located behind cover.
 - 6. Construction:
 - a. 0.0478-inch- thick, corrosion-resistant steel enclosure with baked-enamel finish.
 - b. Removable front cover.
 - c. Wetted parts of transmitter constructed of 17-4 PH stainless steel.
 - d. Threaded, NPS 1/8 process connections on bottom of instrument enclosure.
 - e. 1/2 inch trade size conduit on side of instrument enclosure.
 - f. Screw terminal block for wire connections.
 - g. Vertical plane mounting.
 - h. NEMA 250, Type 4.
 - i. Mounting Bracket: Appropriate for installation.
 - 7. Provide transmitter with three-valve manifold.

- a. Construct manifold of Type 316 stainless steel.
- b. Manifold with threaded, NPS 1/4 process connections.

2.7 SOURCE QUALITY CONTROL

- A. Factory Tests: Test and inspect assembled pressure instruments, as indicated by instrument requirements. Affix standards organization's certification and label.
- B. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Properly support instruments, tubing, piping wiring, and conduit to comply with requirements indicated. Brace all products to prevent lateral movement, sway, or a break in attachment when subjected to a force.
- C. Provide ceiling, floor, roof, wall openings, and sleeves required by installation. Before proceeding with drilling, punching, or cutting, check location first for concealed products that could potentially be damaged. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- D. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by using excessive force or oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- E. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- F. Corrosive Environments:

1. Use products that are suitable for environment to which they are subjected.
2. If possible, avoid or limit use of materials in corrosive environments.
3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
4. Where instruments are located in a corrosive environment and are not corrosive resistant from the manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRICAL POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 PRESSURE INSTRUMENT INSTALLATION

- A. Mounting Location:
 1. Rough-in: Outline instrument-mounting locations before setting instruments and routing, cable, wiring, tubing, and conduit to final location.
 2. Install switches and transmitters for air and liquid pressure associated with individual air-handling units and associated connected ductwork and piping near air-handlings units co-located in air-handling unit system control panel, to provide service personnel a single and convenient location for inspection and service.
 3. Install liquid and steam pressure switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 4. Install air-pressure switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 5. Mount switches and transmitters not required to be mounted within system control panels on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.
 6. Install instruments (except pressure gages) in steam, liquid, and liquid-sealed piped services below their process connection point. Slope tubing down to instrument with a slope of 2 percent.
 7. Install instruments in dry gas and noncondensable vapor piped services above their process connection point. Slope process connection lines up to instrument with a minimum slope of 2 percent.
- B. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.
- C. Duct Pressure Sensors:
 1. Install sensors using manufacturer's recommended upstream and downstream distances.

2. Unless indicated on Drawings, locate sensors approximately 75 percent of distance of longest hydraulic run. Location of sensors shall be submitted and approved before installation.
3. Install mounting hardware and gaskets to make sensor installation airtight.
4. Route tubing from the sensor to transmitter.
5. Use compression fittings at terminations.
6. Install sensor in accordance with manufacturer's instructions.
7. Support sensor to withstand maximum air velocity, turbulence, and vibration encountered to prevent instrument failure.

D. Outdoor Pressure Sensors:

1. Install roof-mounted sensor in least-noticeable location and as far away from exterior walls as possible.
2. Locate wall-mounted sensor in an inconspicuous location.
3. Submit sensor location for approval before installation.
4. Verify signal from sensor is stable and consistent to all connected transmitters. Modify installation to achieve proper signal.
5. Route outdoor signal pipe full size of sensor connection to transmitters. Install branch connection of size required to match to transmitter.
6. Install sensor signal pipe with dirt leg and drain valve below roof penetration.
7. Insulate signal pipe with flexible elastomeric insulation as required to prevent condensation.
8. Connect roof-mounted signal pipe exposed to outdoors to building grounding system.

E. Air-Pressure Differential Switches:

1. Install air-pressure sensor in system for each switch connection. Install sensor in an accessible location for inspection and replacement.
2. A single sensor may be used to share a common signal to multiple pressure instruments.
3. Install access door in duct and equipment to access sensors that cannot be inspected and replaced from outside.
4. Route NPS 3/8 tubing from sensor to switch connection.
5. Do not mount switches on rotating equipment.
6. Install switches in a location free from vibration, heat, moisture, or adverse effects, which could damage the switch and hinder accurate operation.
7. Install switches in an easily accessible location serviceable from floor.
8. Install switches adjacent to system control panel if within 50 feet ; otherwise, locate switch in vicinity of system connection.

F. Liquid-Pressure Differential Switches:

1. Where process connections are located in mechanical equipment room, install switch in convenient and accessible location near system control panel.
2. Where process connections are installed outside mechanical rooms, route processing tubing to mechanical room housing system control panel and locate switch near system control panel.
3. Where multiple switches serving same system are installed in same room, install switches by system to provide service personnel a single and convenient location for inspection and service.
4. System process tubing connection shall be full size of switch connection, but not less than NPS 1/2. Install stainless-steel bushing if required to mate switch to system connection.
5. Connect process tubing from point of system connection and extend to switch.
6. Install isolation valves in process tubing as close to system connection as practical.
7. Install dirt leg and drain valve at each switch connection.
8. Do not mount switches on rotating equipment.
9. Install switches in a location free from vibration, heat, moisture, or adverse effects, which could damage the switch and hinder accurate operation.
10. Install switches in an easily accessible location serviceable from floor.

G. Liquid-Pressure Transmitters:

1. Where process connections are installed in mechanical equipment room, install transmitter in convenient and accessible location near system control panel.
2. Where process connections are installed outside mechanical rooms, route processing tubing to mechanical room housing system control panel and locate transmitter near system control panel.
3. Where multiple transmitters serving same system are installed in same room, install transmitters by system to provide service personnel a single and convenient location for inspection and service.
4. System process tubing connection shall be full size of switch connection, but not less than NPS 1/2. Install stainless-steel bushing if required to mate switch to system connection.
5. Connect process tubing from point of system connection and extend to transmitter.
6. Install isolation valves in process tubing as close to system connection as practical.
7. Install dirt leg and drain valve at each transmitter connection.
8. Do not mount transmitters on equipment.
9. Install in a location free from vibration, heat, moisture, or adverse effects, which could damage and hinder accurate operation.

3.5 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification and on face of ceiling directly below instruments concealed above ceilings.

3.6 CHECKOUT PROCEDURES

- A. Check out installed products before continuity tests, leak tests, and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation with respect to direction of flow, elevation, orientation, insertion depth, or other applicable considerations that impact performance.

3.7 ADJUSTMENT, CALIBRATION, AND TESTING

- A. Description:
 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
 3. For each analog instrument, perform a three-point calibration test for both linearity and accuracy.
 4. Equipment and procedures used for calibration shall comply with instrument manufacturer's recommendations.
 5. Provide diagnostic and test equipment for calibration and adjustment.
 6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
 7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
 8. If, after calibration, indicated performance cannot be achieved, replace out-of-tolerance instruments.

9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.
- B. Analog Signals:
 1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
 2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
- C. Digital Signals:
 1. Check digital signals using a jumper wire.
 2. Check digital signals using an ohmmeter to test for contact.
- D. Sensors: Check sensors at zero, 50, and 100 percent of project design values.
- E. Switches: Calibrate switches to make or break contact at set points indicated.
- F. Transmitters:
 1. Check and calibrate transmitters at zero, 50, and 100 percent of project design values.

END OF SECTION 230923.23

SECTION 230923.27 - TEMPERATURE INSTRUMENTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Air temperature sensors.
 - 2. Air temperature RTD transmitters.
 - 3. Liquid and steam temperature sensors.
 - 4. High-end, commercial-grade, liquid and steam temperature sensors.
 - 5. High-end, commercial-grade, liquid and steam temperature transmitters.
- B. Related Requirements:
 - 1. Section 230923 "Direct-Digital Control System for HVAC" for control equipment and software, relays, electrical power devices, uninterruptible power supply units, wire, and cable.
 - 2. Section 230993 "Sequence of Operations for HVAC Controls" for requirements that relate to Section 230923.27.

1.3 DEFINITIONS

- A. HART (Highway Addressable Remote Transducer) Protocol: The global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring systems through bidirectional communication that provides data access between intelligent field instruments and host systems. A host can be any software application from a technician's hand-held device or laptop to a plant's process control, asset management, safety, or other system using any control platform.
- B. RTD: Resistance temperature detector.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product, including the following:
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
 - 3. Product description with complete technical data, performance curves, and product specification sheets.
 - 4. Installation operation and maintenance instructions, including factors affecting performance.

B. Shop Drawings:

1. Include plans, elevations, sections, and mounting details.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Include number-coded identification system for unique identification of wiring, cable, and tubing ends.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Product installation location shown in relationship to room, duct, pipe, and equipment.
2. Wall-mounted instruments located in finished space showing relationship to light switches, fire-alarm devices, and other installed devices.
3. Sizes and locations of wall access panels for instruments installed behind walls.
4. Sizes and locations of ceiling access panels for instruments installed in inaccessible ceilings.

B. Product Certificates: For each product requiring a certificate.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Environmental Conditions:

1. Instruments shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
2. Instruments and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Instrument's installed location shall dictate following NEMA 250 enclosure requirements:
 - a. Outdoors, Protected: Type 12.
 - b. Outdoors, Unprotected: Type 4.
 - c. Indoors, Heated with Filtered Ventilation: Type 1.
 - d. Indoors, Heated with Non-Filtered Ventilation: Type 12.
 - e. Indoors, Heated and Air Conditioned: Type 1.

- f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: Type 4.
 - 2) Air-Moving Equipment Rooms: Type 1.
- g. Localized Areas Exposed to Washdown: Type 4.
- h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 2.
- i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: Type 4.
- j. Hazardous Locations: Explosion-proof rating for condition.

2.2 AIR TEMPERATURE SENSORS

- A. Provide sensors, controls, instruments, and control interfaces to meet the performance specified herein. Sensors shall be high quality precision electronic type, selected to be compatible with the BCS controllers and appropriate for the service specified herein. Accuracy values specified herein include sensor, wiring, signal conditioning and display accuracies for overall end-to-end performance. Sensors shall be selected to place the expected value in the middle third of the device's range.
- B. Air temperature sensing shall be provided by duct insertion type sensors for supply or return duct temperatures and by extended element averaging type for plenum, and coil entering or leaving temperatures. RTD transmitters shall be a 2-wire, loop-powered device, producing a linear 4-20 mA output corresponding to the temperature span of the connected sensor. The output error shall not exceed 0.1% of calibrated span. Transmitters shall include noninteracting offset and span adjustments and RFI shielding and rejection circuitry to prevent disruption from ambient signals. Transmitter drift shall be less than 0.1°F per year.
- C. Space temperature sensors: space temperature type with setpoint adjustment range of 45°F to 85°F. The setpoint adjustment shall be locked out, overridden, or limited as to time or temperature in software from a central or remote operator's terminal. Precision thermistors may be used in space temperature sensing applications below 200°F. Sensor accuracy over the application range shall be minimum 0.5°F between the range of 32°F to 150°F including sensor error and A/D conversion resolution error. Sensor manufacturer shall utilize 100% screening to verify accuracy. Thermistors shall be pre-aged and inherently stable. Stability error of the thermistor over 5 years shall not exceed 0.25°F cumulative. Sensor element and leads shall be encapsulated. Bead thermistors shall not be used. Space temperature sensors shall include a communications port for local connection of a portable test/terminal device for communications/programming access to the associated BCS controller.
 - 1. Space temperature sensors in operating rooms, labor and delivery rooms, and special procedure (radiology) rooms shall have covers with visible temperature indicator integral to the sensor, occupant override push button integral or adjacent to the sensor assembly, and accessible means of setpoint adjustment.
 - 2. Space temperature sensors in patient rooms shall have blank cover and accessible means of setpoint adjustment.
- D. Platinum RTDs: Common Requirements:
 - 1. 100 or 1000 ohms at zero deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
 - 2. Two-wire, PTFE-insulated, 22-gage stranded copper leads.
 - 3. Performance Characteristics:
 - a. Range: Minus 50 to 275 deg F.
 - b. Interchangeable Accuracy: At 32 deg F within 0.5 deg F.

- c. Repeatability: Within 0.5 deg F.
 - d. Self-Heating: Negligible.
- 4. Transmitter Requirements:
 - a. Transmitter required for each 100-ohm RTD.
 - b. Transmitter optional for 1000-ohm RTD, contingent on compliance with end-to-end control accuracy.
- E. Platinum RTD, Single-Point Air Temperature Duct Sensors:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Minco.
 - 2. 100 or 1000 ohms.
 - 3. Temperature Range: Minus 50 to 275 deg F.
 - 4. Probe: Single-point sensor with a stainless-steel sheath.
 - 5. Length: As required by application to achieve tip at midpoint of air tunnel, up to 18 inches.
 - 6. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
 - 7. Gasket for attachment to duct or equipment to seal penetration airtight.
 - 8. Conduit Connection: 1/2-inch trade size.
- F. Platinum RTD, Air Temperature Averaging Sensors:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Minco.
 - 2. 100 or 1000 ohms.
 - 3. Temperature Range: Minus 50 to 275 deg F.
 - 4. Multiple sensors to provide average temperature across entire length of sensor.
 - 5. Rigid probe of aluminum, brass, copper, or stainless-steel sheath.
 - 6. Flexible probe of aluminum, brass, copper, or stainless-steel sheath and formable to a 4-inch radius.
 - 7. Length: As required by application to cover entire cross section of air tunnel.
 - 8. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
 - 9. Gasket for attachment to duct or equipment to seal penetration airtight.
 - 10. Conduit Connection: 1/2-inch trade size.
- G. Platinum RTD Outdoor Air Temperature Sensors:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Minco.
 - 2. or 1000 ohms.
 - 3. Temperature Range: Minus 50 to 275 deg F.
 - 4. Probe: Single-point sensor with a stainless-steel sheath.
 - 5. Solar Shield: Stainless steel.
 - 6. Enclosure: NEMA 250, Type 4 or 4X junction box or combination conduit and outlet box with removable cover and gasket.
 - 7. Conduit Connection: 1/2-inch trade size.

H. Platinum RTD Space Air Temperature Sensors:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Minco.
2. or 1000 ohms.
3. Temperature Range: Minus 50 to 212 deg F.
4. Sensor assembly shall include a temperature sensing element mounted under a flush, brushed-aluminum cover.
5. Provide a mounting plate that is compatible with the surface shape that it is mounted to and electrical box used.
6. Concealed wiring connection.

I. Thermal Resistors (Thermistors): Common Requirements:

1. 10,000 ohms at 25 deg C and a temperature coefficient of 23.5 ohms/ohm/deg C.
2. Two-wire, PTFE-insulated, 22-gage stranded copper leads.
3. Performance Characteristics:
 - a. Range: Minus 50 to 275 deg F.
 - b. Interchangeable Accuracy: At 77 deg F within 0.5 deg F.
 - c. Repeatability: Within 0.5 deg F.
 - d. Drift: Within 0.5 deg F over 10 years.
 - e. Self-Heating: Negligible.
4. Transmitter optional, contingent on compliance with end-to-end control accuracy.

J. Space Air Temperature Sensors for Use with DDC Controllers Controlling Terminal Units:

1. 100- or 1000-ohm platinum RTD or thermistor.
2. Thermistor:
 - a. Pre-aged, burned in, and coated with glass; inserted in a metal sleeve; and entire unit encased in epoxy.
 - b. Thermistor drift shall be less than plus or minus 0.5 deg F over 10 years.
3. Temperature Transmitter Requirements:
 - a. Mating transmitter required with each 100-ohm RTD.
 - b. Mating transmitters optional for 1000-ohm RTD and thermistor, contingent on compliance with end-to-end control accuracy.
4. Provide digital display of sensed temperature.
5. Provide sensor with local control.
 - a. Local override to turn HVAC on.
 - b. Local adjustment of temperature set point.
 - c. Both features shall be capable of manual override through control system operator.

2.3 AIR TEMPERATURE RTD TRANSMITTERS

A. Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Minco.

- B. Source Limitations: Obtain temperature-measuring sensors and transmitters and airflow from single manufacturer.
- C. House electronics in NEMA 250 enclosure.
 - 1. Duct: Type 1.
 - 2. Outdoor: Type 4.
- D. Conduit Connection: 1/2-inch trade size.
- E. Functional Characteristics:
 - 1. Input:
 - a. 1000-ohm platinum RTD temperature coefficient of 0.00385 ohm/ohm/deg C, two-wire sensors.
 - 2. Span (Adjustable):
 - a. Space: 40 to 90 deg F.
 - b. Supply Air Cooling and Heating: 40 to 120 deg F.
 - c. Supply Air Cooling Only: 40 to 90 deg F.
 - d. Supply Air Heating Only: 40 to 120 deg F.
 - e. Exhaust Air: 50 to 100 deg F.
 - f. Return Air: 50 to 100 deg F.
 - g. Mixed Air: Minus 40 to 140 deg F.
 - h. Outdoor: Minus 40 to 140 deg F.
 - 3. Output: 4- to 20-mA dc, linear with temperature; RFI insensitive; minimum drive load of 600 ohms at 24-V dc.
 - 4. Zero and span field adjustments, plus or minus 5 percent of span. Minimum span of 50 deg F.
 - 5. Match sensor with temperature transmitter and factory calibrate together.
- F. Performance Characteristics:
 - 1. Calibration Accuracy: Within 0.1 percent of the span.
 - 2. Stability: Within 0.2 percent of the span for at least 6 months.
 - 3. Combined Accuracy: Within 0.5 percent.

2.4 LIQUID AND STEAM TEMPERATURE SENSORS, COMMERCIAL GRADE

- A. Water sensors used for Btu calculations or control as indicated on the I/O summaries shall have an accuracy of $\pm 0.25^{\circ}\text{F}$ at 32°F . Sensors used for Btu calculations shall be matched pairs at the calibration point. Temperature sensor stability errors shall not exceed 0.25°F cumulative over a 5 year period. Provide thermowells as specified herein and insertion type sensors as specified herein for water temperature sensing.
- B. RTD:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. MAMAC Systems, Inc.

2. Description:

- a. Platinum with a value of 100 or 1000 ohms at zero deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
- b. Encase RTD in a stainless-steel sheath with a 0.25-inch OD.
- c. Sensor Length: 4, 6, or 8 inches as required by application.
- d. Process Connection: Threaded, NPS 1/2.
- e. Two-stranded copper lead wires.
- f. Powder-coated steel enclosure, NEMA 250, Type 4.
- g. Conduit Connection: 1/2-inch trade size.
- h. Performance Characteristics:
 - 1) Range: Minus 40 to 210 deg F.
 - 2) Interchangeable Accuracy: Within 0.54 deg F at 32 deg F.

C. Thermowells:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. MAMAC Systems, Inc.
2. Stem: Straight or stepped shank formed from solid bar stock.
3. Material: Brass or stainless steel.
4. Process Connection: Threaded, NPS 3/4.
5. Sensor Connection: Threaded, NPS 1/2.
6. Bore: Sized to accommodate sensor with tight tolerance between sensor and well.
7. Furnish thermowells installed in insulated pipes and equipment with an extended neck.
8. Length: 4, 6, or 8 inches as required by application.
9. Thermowells furnished with heat-transfer compound to eliminate air gap between wall of sensor and thermowell and to reduce time constant.

2.5 LIQUID AND STEAM TEMPERATURE SENSORS, HIGH-END COMMERCIAL GRADE

A. RTD:

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Minco.
2. Resistance temperature sensors shall comply with IEC 60751, Class B requirements.
3. Platinum with a value of 100 ohms at zero deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
4. Encase RTD in a Type 316 stainless-steel sheath with a 0.25-inch OD.
5. Provide four-wire, PTFE-insulated, nickel-coated, 22-gage, stranded copper leads.
6. Provide spring-loaded RTDs for thermowell installations.
7. Performance Characteristics:
 - a. Range: Minus 328 to 932 deg F.
 - b. Interchangeable Accuracy: Within 0.54 deg F at 32 deg F.
 - c. Stability: Within 0.05 percent maximum ice-point resistance shift after 1000 hours at 752 deg F.

- d. Hysteresis: Within 0.04 percent of range.
- e. Response Time: 62.8 percent of change in 4 seconds with water flowing across sensor at 3 fps.

B. Thermowells:

- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Minco.
- 2. Stem: Straight or stepped or tapered shank formed from solid bar stock.
- 3. Material: Type 304 or Type 316 stainless steel.
- 4. Process Connection: Threaded, NPS 3/4
- 5. Sensor Connection: Threaded, NPS 1/2
- 6. Bore: Sized to accommodate sensor with tight tolerance between sensor and well.
- 7. Furnish thermowells installed in insulated pipes and equipment with an extended neck that extends beyond the face of the insulation covering.
- 8. Length: As required by application and pipe size.
- 9. Thermowells furnished with heat-transfer compound to eliminate air gap between wall of sensor and thermowell and to reduce time constant.

C. Connection Heads:

- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Minco.
- 2. Housing: Low-copper cast-aluminum alloy, complying with NEMA 250, Type 4.
- 3. Terminals: Six or eight as required by sensor.
- 4. Conduit Connection: 1/2-inch trade size.
- 5. Sensor Connection: NPS 1/2.

D. Assembly: Sensor manufacturer shall furnish sensor, thermowell, and sensor connection head to provide a matched assembly.

2.6 LIQUID AND STEAM TEMPERATURE TRANSMITTERS, COMMERCIAL GRADE

A. Manufacturers: Subject to compliance with requirements, provide products by the following:

- 1. Minco.

B. House electronics in NEMA 250, Type 4 enclosure.

C. Enclosure Connection: 1/2-inch trade size.

D. Functional Characteristics:

- 1. Input: 100-ohm platinum RTD temperature coefficient of 0.00385 ohm/ohm/deg C, two- or three-wire sensors.
- 2. Default Span (Adjustable):
 - a. Chilled Water: Zero to 100 deg F.
 - b. Condenser Water: Zero to 120 deg F.

- c. Heating Hot Water: 32 to 212 deg F.
 - d. Heat Recovery: Zero to 120 deg F.
 - 3. Output: 4- to 20-mA dc, linear with temperature; RFI insensitive; minimum drive load of 600 ohms at 24-V dc.
 - 4. Zero and span field adjustments, plus or minus 5 percent of span. Minimum span of 50 deg F.
 - 5. Match sensor with temperature transmitter and factory calibrate together. Each matched sensor and transmitter set shall include factory calibration data traceable to NIST.
- E. Performance Characteristics:
- 1. Calibration Accuracy: Within 0.1 percent of the span.
 - 2. Stability: Within 0.2 percent of the span for at least 6 months.
 - 3. Combined Accuracy: Within 0.5 percent.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
- C. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Install products level, plumb, parallel, and perpendicular with building construction.
- B. Fastening Hardware:
 - 1. Stillson wrenches, pliers, and other tools that cause injury to or mar surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening nuts.
 - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
 - 3. Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
- C. Install products in locations that are accessible and that permit calibration and maintenance from floor, equipment platforms, or catwalks. Where ladders are required for Owner's access, confirm unrestricted ladder placement is possible under occupied condition.
- D. Corrosive Environments:
 - 1. Use products that are suitable for environment to which they are subjected.
 - 2. If possible, avoid or limit use of materials in corrosive environments.

3. When conduit is in contact with a corrosive environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment.
4. Where instruments are located in a corrosive environment and are not corrosive resistant from manufacturer, field install products in a NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.3 ELECTRIC POWER

- A. Furnish and install electrical power to products requiring electrical connections.
- B. Furnish and install circuit breakers. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers."
- C. Furnish and install power wiring. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- D. Furnish and install raceways. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

3.4 TEMPERATURE INSTRUMENT INSTALLATIONS

- A. Mounting Location:
 1. Roughing In:
 - a. Outline instrument mounting locations before setting instruments and routing cable, wiring, tubing, and conduit to final location.
 - b. Provide independent inspection to confirm that proposed mounting locations comply with requirements indicated and approved submittals.
 - 1) Indicate dimensioned locations with mounting height for all surface-mounted products on Shop Drawings.
 - 2) Do not begin installation without submittal approval of mounting location.
 - c. Complete installation rough-in only after confirmation by independent inspection is complete and approval of location is documented for review by Owner and Architect on request.
 2. Install switches and transmitters for air and liquid temperature associated with individual air-handling units and associated connected ductwork and piping near air-handling units co-located in air-handling unit system control panel to provide service personnel a single and convenient location for inspection and service.
 3. Install liquid and steam temperature switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 4. Install air temperature switches and transmitters for indoor applications in mechanical equipment rooms. Do not locate in user-occupied space unless indicated specifically on Drawings.
 5. Mount switches and transmitters on walls, floor-supported freestanding pipe stands, or floor-supported structural support frames. Use manufacturer's mounting brackets to accommodate field mounting. Securely support and brace products to prevent vibration and movement.

B. Special Mounting Requirements:

1. Protect products installed outdoors from solar radiation, building and wind effect with stand-offs and shields constructed of Type 316 stainless.
2. Temperature instruments having performance impacted by temperature of mounting substrate shall be isolated with an insulating barrier located between instrument and substrate to eliminate effect. Where instruments requiring insulation are located in finished space, conceal insulating barrier in a cover matching the instrument cover.

C. Mounting Height:

1. Mount temperature instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
2. Mount switches and transmitters located in mechanical equipment rooms and other similar space not subject to code or state and Federal accessibility requirements within a range of 42 to 72 inches above the adjacent floor, grade, or service catwalk or platform.
 - a. Make every effort to mount at 60 inches.

D. Seal penetrations to ductwork, plenums, and air-moving equipment to comply with duct static-pressure class and leakage and seal classes indicated using neoprene gaskets or grommets.

E. Space Temperature Sensor Installation:

1. Conceal assembly in an electrical box of sufficient size to house sensor and transmitter, if provided.
2. Install electrical box with a faceplate to match sensor cover if sensor cover does not completely cover electrical box.
3. In finished areas, recess electrical box within wall.
4. In unfinished areas, electrical box may be surface mounted if electrical light switches are surface mounted. Use a cast-aluminum electric box for surface-mounted installations.
5. Align electrical box with other electrical devices such as visual alarms and light switches located in the vicinity to provide a neat and well-thought-out arrangement. Where possible, align in both horizontal and vertical axis.

F. Outdoor Air Temperature Sensor Installation:

1. Mount sensor in a discrete location facing north.
2. Protect installed sensor from solar radiation and other influences that could impact performance.
3. If required to have a transmitter, mount transmitter remote from sensor in an accessible and serviceable location indoors.

G. Single-Point Duct Temperature Sensor Installation:

1. Install single-point-type, duct-mounted, supply- and return-air temperature sensors. Install sensors in ducts with sensitive portion of the element installed in center of duct cross section and located to sense near average temperature. Do not exceed 24 inches in sensor length.
2. Install return-air sensor in location that senses return-air temperature without influence from outdoor or mixed air.
3. Rigidly support sensor to duct and seal penetration airtight.
4. If required to have transmitter, mount transmitter remote from sensor at accessible and serviceable location.

H. Averaging Duct Temperature Sensor Installation:

1. Install averaging-type air temperature sensor for temperature sensors located within air-handling units, similar equipment, and large ducts with air tunnel cross-sectional area of 20 sq. ft. and larger.
2. Install sensor length to maintain coverage over entire cross-sectional area. Install multiple sensors where required to maintain the minimum coverage.
3. Fasten and support sensor with manufacturer-furnished clips to keep sensor taut throughout entire length.
4. If required to have transmitter, mount transmitter in an accessible and serviceable location.

I. Low-Limit Air Temperature Switch Installation:

1. Install multiple low-limit switches to maintain coverage over entire cross-sectional area of air tunnel.
2. Fasten and support sensing element with manufacturer-furnished clips to keep element taut throughout entire length.
3. Mount switches outside of airstream at a location and mounting height to provide easy access for switch set-point adjustment and manual reset.
4. Install on entering side of cooling coil unless otherwise indicated on Drawings.

J. Liquid Temperature Sensor Installation:

1. Assembly shall include sensor, thermowell and connection head.
2. For pipe NPS 4 and larger, install sensor and thermowell length to extend into pipe between 50 to 75 percent of pipe cross section.
3. For pipe smaller than NPS 4:
 - a. Install reducers to increase pipe size to NPS 4 at point of thermowell installation.
 - b. For pipe sizes NPS 2-1/2 and NPS 3, thermowell and sensor may be installed at pipe elbow or tee to achieve manufacturer-recommended immersion depth in lieu of increasing pipe size.
 - c. Minimum insertion depth shall be 2-1/2 inches.
4. Install matching thermowell.
5. Fill thermowell with heat-transfer fluid before inserting sensor.
6. Tip of spring-loaded sensors shall contact inside of thermowell.
7. For insulated piping, install thermowells with extension neck to extend beyond face of insulation.
8. Install thermowell in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement. If top dead center location is not possible due to field constraints, install thermowell at location along top half of pipe.
9. For applications with transmitters, mount transmitter remote from sensor in an accessible and serviceable location from floor service platform or catwalk.

3.5 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install engraved phenolic nameplate with instrument identification and on face of ceiling directly below instruments concealed above ceilings.

3.6 CLEANING

- A. Remove grease, mastic, adhesives, dust, dirt, stains, fingerprints, labels, and other foreign materials from exposed interior and exterior surfaces.
- B. Wash and shine glazing.
- C. Polish glossy surfaces to a clean shine.

3.7 CHECK-OUT PROCEDURES

- A. Check installed products before continuity tests, leak tests, and calibration.
- B. Check temperature instruments for proper location and accessibility.
- C. Verify sensing element type and proper material.
- D. Verify location and length.
- E. Verify that wiring is correct and secure.

3.8 ADJUSTMENT, CALIBRATION, AND TESTING

A. Description:

- 1. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
- 2. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
- 3. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
- 4. Equipment and procedures used for calibration shall meet instrument manufacturer's written instructions.
- 5. Provide diagnostic and test equipment for calibration and adjustment.
- 6. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
- 7. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
- 8. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
- 9. Comply with field-testing requirements and procedures indicated by ASHRAE Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements and to supplement requirements indicated.

B. Analog Signals:

- 1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
- 2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
- 3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistance source.

C. Digital Signals:

- 1. Check digital signals using a jumper wire.
- 2. Check digital signals using an ohmmeter to test for contact.

D. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

- E. Switches: Calibrate switches to make or break contact at set points indicated.
- F. Transmitters:
 - 1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
 - 2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistance source.

3.9 FIELD QUALITY CONTROL

- A. Testing Agency: a qualified testing agency to perform tests and inspections.
- B. Perform the following tests and inspections:
 - 1. Perform according to manufacturer's written instruction.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- C. Prepare test and inspection reports.

3.10 ADJUSTING

- A. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

END OF SECTION 230923.27

SECTION 231123 - FACILITY NATURAL-GAS PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Pipes, tubes, and fittings.
 - 2. Piping specialties.
 - 3. Piping and tubing joining materials.
 - 4. Manual gas shutoff valves.
 - 5. Pressure regulators.

1.3 DEFINITIONS

- A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.
- B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of the following:
 - 1. Piping specialties.
 - 2. Valves. Include pressure rating, capacity, settings, and electrical connection data of selected models.
 - 3. Pressure regulators. Indicate pressure ratings and capacities.
 - 4. Service meters. Indicate pressure ratings and capacities. Include bypass fittings supports.
 - 5. Dielectric fittings.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans and details, drawn to scale, on which natural-gas piping is shown and coordinated with other installations, using input from installers of the items involved.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For pressure regulators to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.
- B. Store and handle pipes and tubes having factory-applied protective coatings to avoid damaging coating, and protect from direct sunlight.

1.9 PROJECT CONDITIONS

- A. Perform site survey, research public utility records, and verify existing utility locations. Contact utility-locating service for area where Project is located.

1.10 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.
- B. Coordinate requirements for access panels and doors for valves installed concealed behind finished surfaces. Comply with requirements in Section 083113 "Access Doors and Frames."

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Minimum Operating-Pressure Ratings:
 - 1. Piping and Valves: 100 psig minimum unless otherwise indicated.
 - 2. Service Regulators: 100 psig minimum unless otherwise indicated.
 - 3. Minimum Operating Pressure of Service Meter: 20 psig.
- B. Natural-Gas System Pressure within Buildings: 0.5 psig or less.

2.2 PIPES, TUBES, AND FITTINGS

- A. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
 - 1. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.
 - 2. Wrought-Steel Welding Fittings: ASTM A 234/A 234M for butt welding and socket welding.

3. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.
4. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, minimum Class 150, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
 - a. Material Group: 1.1.
 - b. End Connections: Threaded or butt welding to match pipe.
 - c. Lapped Face: Not permitted underground.
 - d. Gasket Materials: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound metal gaskets.
 - e. Bolts and Nuts: ASME B18.2.1, carbon steel aboveground and stainless steel underground.

2.3 PIPING SPECIALTIES

A. Appliance Flexible Connectors:

1. Indoor, Fixed-Appliance Flexible Connectors: Comply with ANSI Z21.24.
2. Operating-Pressure Rating: 0.5 psig.
3. End Fittings: Zinc-coated steel.
4. Threaded Ends: Comply with ASME B1.20.1.
5. Maximum Length: 72 inches

B. Y-Pattern Strainers:

1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.
3. Strainer Screen: 60-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 125 psig.

2.4 JOINING MATERIALS

A. Joint Compound and Tape: Suitable for natural gas.

B. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

2.5 MANUAL GAS SHUTOFF VALVES

A. General Requirements for Metallic Valves, NPS 2 and Smaller: Comply with ASME B16.33.

1. CWP Rating: 125 psig.
2. Threaded Ends: Comply with ASME B1.20.1.
3. Dryseal Threads on Flare Ends: Comply with ASME B1.20.3.
4. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
5. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction for valves 1 inch and smaller.
6. Service Mark: Valves 1-1/4 inches to NPS 2 shall have initials "WOG" permanently marked on valve body.

- B. General Requirements for Metallic Valves, NPS 2-1/2 and Larger: Comply with ASME B16.38.
1. CWP Rating: 125 psig.
 2. Flanged Ends: Comply with ASME B16.5 for steel flanges.
 3. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 4. Service Mark: Initials "WOG" shall be permanently marked on valve body.
- C. Two-Piece, Full-Port, Bronze Ball Valves with Bronze Trim: MSS SP-110.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. A.Y. McDonald Mfg. Co.
 - b. Apollo Valves; a part of Aalberts Integrated Piping Systems.
 - c. BrassCraft Manufacturing Co.; a Masco company.
 2. Body: Bronze, complying with ASTM B 584.
 3. Ball: Chrome-plated bronze.
 4. Stem: Bronze; blowout proof.
 5. Seats: Reinforced TFE; blowout proof.
 6. Packing: Threaded-body packnut design with adjustable-stem packing.
 7. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 8. CWP Rating: 600 psig.
 9. Listing: Valves NPS 1 and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 10. Service: Suitable for natural-gas service with "WOG" indicated on valve body.
- D. Bronze Plug Valves: MSS SP-78.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. A.Y. McDonald Mfg. Co.
 - b. Lee Brass Company.
 2. Body: Bronze, complying with ASTM B 584.
 3. Plug: Bronze.
 4. Ends: Threaded, socket, or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 5. Operator: Square head or lug type with tamperproof feature where indicated.
 6. Pressure Class: 125 psig.
 7. Listing: Valves NPS 1 and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
 8. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

2.6 PRESSURE REGULATORS

- A. General Requirements:
1. Single stage and suitable for natural gas.
 2. Steel jacket and corrosion-resistant components.
 3. Elevation compensator.
 4. End Connections: Threaded for regulators NPS 2 and smaller; flanged for regulators NPS 2-1/2 and larger.

B. Service Pressure Regulators: Comply with ANSI Z21.80.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Actaris: a brand of ITT Controls.
 - b. American Meter Company.
 - c. Fischer; Emerson Electric Co., Automation Solutions.
2. Body and Diaphragm Case: Cast iron or die-cast aluminum.
3. Springs: Zinc-plated steel; interchangeable.
4. Diaphragm Plate: Zinc-plated steel.
5. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
6. Orifice: Aluminum; interchangeable.
7. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
8. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
9. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.
10. Overpressure Protection Device: Factory mounted on pressure regulator.
11. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.

C. Appliance Pressure Regulators: Comply with ANSI Z21.18.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Dormont; A Watts Water Technologies Company.
 - b. Eaton.
 - c. Maxitrol Company.
2. Body and Diaphragm Case: Die-cast aluminum.
3. Springs: Zinc-plated steel; interchangeable.
4. Diaphragm Plate: Zinc-plated steel.
5. Seat Disc: Nitrile rubber.
6. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
7. Factory-Applied Finish: Minimum three-layer polyester and polyurethane paint finish.
8. Regulator may include vent limiting device, instead of vent connection, if approved by authorities having jurisdiction.
9. Maximum Inlet Pressure: 2 psig.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for natural-gas piping system to verify actual locations of piping connections before equipment installation.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Close equipment shutoff valves before turning off natural gas to premises or piping section.

- B. Inspect natural-gas piping according to North Carolina Fuel Gas Code the International Fuel Gas Code to determine that natural-gas utilization devices are turned off in piping section affected.
- C. Comply with North Carolina Fuel Gas Code requirements for prevention of accidental ignition.

3.3 OUTDOOR PIPING INSTALLATION

- A. Comply with North Carolina Fuel Gas Code for installation and purging of natural-gas piping.
- B. Steel Piping with Protective Coating:
 - 1. Apply joint cover kits to pipe after joining to cover, seal, and protect joints.
- C. Install fittings for changes in direction and branch connections.
- D. Install pressure gage upstream and downstream from each service regulator. Pressure gages are specified in Section 230519 "Meters and Gages for HVAC Piping."

3.4 INDOOR PIPING INSTALLATION

- A. Comply with North Carolina Fuel Gas Code for installation and purging of natural-gas piping.
- B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- C. Arrange for pipe spaces, chases, slots, sleeves, and openings in building structure during progress of construction, to allow for mechanical installations.
- D. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- E. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- F. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- G. Locate valves for easy access.
- H. Install natural-gas piping at uniform grade of 2 percent down toward drip and sediment traps.
- I. Install piping free of sags and bends.
- J. Install fittings for changes in direction and branch connections.
- K. Verify final equipment locations for roughing-in.
- L. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.

- M. Drips and Sediment Traps: Install drips at points where condensate may collect, including service-meter outlets. Locate where accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.
 - 1. Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Use nipple a minimum length of 3 pipe diameters, but not less than 3 inches long and same size as connected pipe. Install with space below bottom of drip to remove plug or cap.
- N. Extend relief vent connections for service regulators, line regulators, and overpressure protection devices to outdoors and terminate with weatherproof vent cap.
- O. Conceal pipe installations in walls, pipe spaces, utility spaces, above ceilings, below grade or floors, and in floor channels unless indicated to be exposed to view.
- P. Concealed Location Installations: Except as specified below, install concealed natural-gas piping and piping installed under the building in containment conduit constructed of steel pipe with welded joints as described in Part 2. Install a vent pipe from containment conduit to outdoors and terminate with weatherproof vent cap.
 - 1. Above Accessible Ceilings: Natural-gas piping, fittings, valves, and regulators may be installed in accessible spaces without containment conduit.
 - 2. In Walls or Partitions: Protect tubing installed inside partitions or hollow walls from physical damage using steel striker barriers at rigid supports.
 - a. Exception: Tubing passing through partitions or walls does not require striker barriers.
 - 3. Prohibited Locations:
 - a. Do not install natural-gas piping in or through circulating air ducts, clothes or trash chutes, chimneys or gas vents (flues), ventilating ducts, or dumbwaiter or elevator shafts.
 - b. Do not install natural-gas piping in solid walls or partitions.
- Q. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.
- R. Connect branch piping from top or side of horizontal piping.
- S. Install unions in pipes NPS 2 and smaller, adjacent to each valve, at final connection to each piece of equipment. Unions are not required at flanged connections.
- T. Do not use natural-gas piping as grounding electrode.
- U. Install strainer on inlet of each line-pressure regulator and automatic or electrically operated valve.
- V. Install pressure gage upstream and downstream from each line regulator. Pressure gages are specified in Section 230519 "Meters and Gages for HVAC Piping."
- W. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- X. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- Y. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

3.5 VALVE INSTALLATION

- A. Install manual gas shutoff valve for each gas appliance ahead of corrugated stainless-steel tubing, aluminum, or copper connector.
- B. Install regulators and overpressure protection devices with maintenance access space adequate for servicing and testing.

3.6 PIPING JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Threaded Joints:
 - 1. Thread pipe with tapered pipe threads complying with ASME B1.20.1.
 - 2. Cut threads full and clean using sharp dies.
 - 3. Ream threaded pipe ends to remove burrs and restore full inside diameter of pipe.
 - 4. Apply appropriate tape or thread compound to external pipe threads unless dryseal threading is specified.
 - 5. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- D. Welded Joints:
 - 1. Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators.
 - 2. Bevel plain ends of steel pipe.
 - 3. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.
- E. Flanged Joints: Install gasket material, size, type, and thickness appropriate for natural-gas service. Install gasket concentrically positioned.
- F. Flared Joints: Cut tubing with roll cutting tool. Flare tube end with tool to result in flare dimensions complying with SAE J513. Tighten finger tight, then use wrench. Do not overtighten.

3.7 HANGER AND SUPPORT INSTALLATION

- A. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Comply with requirements for pipe hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- C. Install hangers for steel piping, with maximum horizontal spacing and minimum rod diameters, to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.
- D. Support horizontal piping within 12 inches of each fitting.

- E. Support vertical runs of steel piping to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

3.8 CONNECTIONS

- A. Connect to utility's gas main according to utility's procedures and requirements.
- B. Install natural-gas piping electrically continuous, and bonded to gas appliance equipment grounding conductor of the circuit powering the appliance according to NFPA 70.
- C. Install piping adjacent to appliances to allow service and maintenance of appliances.
- D. Connect piping to appliances using manual gas shutoff valves and unions. Install valve within 72 inches of each gas-fired appliance and equipment. Install union between valve and appliances or equipment.
- E. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.

3.9 LABELING AND IDENTIFYING

3.10 PAINTING

- A. Comply with requirements in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting" for painting interior and exterior natural-gas piping.
- B. Paint exposed, exterior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components, with factory-applied paint or protective coating.
 - 1. Alkyd System: MPI EXT 5.1D.
 - a. Prime Coat: Alkyd anticorrosive metal primer.
 - b. Intermediate Coat: Exterior alkyd enamel matching topcoat.
 - c. Topcoat: Exterior alkyd enamel (flat).
 - d. Color: Gray.
- C. Paint exposed, interior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components, with factory-applied paint or protective coating.
 - 1. Latex Over Alkyd Primer System: MPI INT 5.1Q.
 - a. Prime Coat: Alkyd anticorrosive metal primer.
 - b. Intermediate Coat: Interior latex matching topcoat.
 - c. Topcoat: Interior latex (flat) (satin).
 - d. Color: Gray.
- D. Damage and Touchup: Repair marred and damaged factory-applied finishes with materials and by procedures to match original factory finish.

3.11 OUTDOOR PIPING SCHEDULE

- A. Aboveground natural-gas piping shall be the following:
 - 1. Steel pipe with wrought-steel fittings and welded joints.

3.12 INDOOR PIPING SCHEDULE FOR SYSTEM PRESSURES MORE THAN 0.5 PSIG AND LESS THAN 5 PSIG

- A. Aboveground, branch piping NPS 1 and smaller shall be the following:
 - 1. Steel pipe with malleable-iron fittings and threaded joints.
- B. Aboveground, distribution piping shall be the following:
 - 1. Steel pipe with steel welding fittings and welded joints.

3.13 ABOVEGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

- A. Valves for pipe sizes NPS 2 and smaller at service meter shall be one of the following:
 - 1. Two-piece, -port, bronze ball valves with bronze trim.
 - 2. Bronze plug valve.
- B. Distribution piping valves for pipe sizes NPS 2 and smaller shall be the following:
 - 1. Two-piece, full -port, bronze ball valves with bronze trim.
- C. Valves in branch piping for single appliance shall be the following:
 - 1. Two-piece, full -port, bronze ball valves with bronze trim.

END OF SECTION 231123

SECTION 232113 - HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Copper tube and fittings.
 - 2. Steel pipe and fittings.
 - 3. Joining materials.
 - 4. Transition fittings.
 - 5. Dielectric fittings.
 - 6. Bypass chemical feeder.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of the following:
 - 1. Pipe and tube.
 - 2. Fittings.
 - 3. Joining materials.
 - 4. Transition fittings.
 - 5. Bypass chemical feeder.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Piping layout, or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.
- B. Qualification Data: For Installer.
- C. Welding certificates.

1.5 QUALITY ASSURANCE

- A. Installer Qualifications:
 - 1. Installers of Pressure-Sealed Joints: Installers shall be certified by pressure-seal joint manufacturer as having been trained and qualified to join piping with pressure-seal pipe couplings and fittings.
 - 2. Fiberglass Pipe and Fitting Installers: Installers of RTRF and RTRP shall be certified by manufacturer of pipes and fittings as having been trained and qualified to join fiberglass piping with manufacturer-recommended adhesive.

- B. Steel Support Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- C. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.
 - 1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.
 - 2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:
 - 1. Hot-Water Heating Piping: 200 psig at 200 deg F.
 - 2. Chilled-Water Piping: 150 psig 73 deg F.
 - 3. Makeup-Water Piping: 125 psig at 200 deg F.
 - 4. Condensate-Drain Piping: 150 deg F.
 - 5. Air-Vent Piping: 180 deg F.
 - 6. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

2.2 COPPER TUBE AND FITTINGS

- A. Drawn-Temper Copper Tube: ASTM B88, Type L and ASTM B88, Type M.
- B. Wrought-Copper, Solder-Joint Fittings: ASME B16.22, pressure fittings.
- C. Bronze Flanges: ASME B16.24, Class 150, with solder-joint ends.
- D. Wrought Copper Unions: ASME B16.22.
- E. Copper-Tube, Pressure-Seal-Joint Fittings:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Apollo Valves; a part of Aalberts Integrated Piping Systems.
 - b. Copper Press Brand; Merit Brass Company.
 - c. Elkhart Products Corporation; a part of Aalberts Integrated Piping Systems.
 - d. Mueller Streamline Co.; a company of Mueller Industries.
 - e. NIBCO INC.
 - 2. Fittings: Cast-brass, cast-bronze, or wrought-copper with EPDM O-ring seal in each end.
 - 3. Minimum 200-psig working-pressure rating at 250 deg F.

2.3 STEEL PIPE AND FITTINGS

- A. Steel Pipe: ASTM A53/A53M, black steel with plain ends; welded and seamless, Grade B, and wall thickness as indicated in "Piping Applications" Article.
- B. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in "Piping Applications" Article.
- C. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" Article.
- D. Wrought-Steel Fittings: ASTM A234/A234M, wall thickness to match adjoining pipe.
- E. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
 - 1. Material Group: 1.1.
 - 2. End Connections: Butt welding.
 - 3. Facings: Raised face.
- F. Steel Pipe Nipples: ASTM A733, made of same materials and wall thicknesses as pipe in which they are installed.

2.4 JOINING MATERIALS

- A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.
 - 1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless otherwise indicated.
 - a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
 - b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.
- B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.
- C. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer unless otherwise indicated.
- D. Solder Filler Metals: ASTM B32, lead-free alloys. Include water-flushable flux according to ASTM B813.
- E. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.
- F. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

2.5 TRANSITION FITTINGS

- A. Plastic-to-Metal Transition Fittings:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Charlotte Pipe and Foundry Company.

- b. IPEX USA LLC.
 - 2. One-piece fitting with one threaded brass or copper insert and one solvent-cement-joint end of material and wall thickness to match plastic pipe material.
- B. Plastic-to-Metal Transition Unions:
- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. aquatherm.
 - b. Charlotte Pipe and Foundry Company.
 - c. IPEX USA LLC.
 - d. NIBCO INC.
 - 2. Brass or copper end, solvent-cement-joint end of material and wall thickness to match plastic pipe material, rubber gasket, and threaded union.

2.6 DIELECTRIC FITTINGS

- A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.
- B. Dielectric Unions:
- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. A.Y. McDonald Mfg. Co.
 - b. Capitol Manufacturing Company.
 - c. GF Piping Systems: Georg Fischer LLC.
 - d. HART Industrial Unions, LLC.
 - e. Jomar Valve.
 - f. Matco-Norca.
 - 2. Description:
 - a. Standard: ASSE 1079.
 - b. Pressure Rating: 150 psig minimum at 200 deg F.
 - c. End Connections: Solder-joint copper alloy and threaded ferrous.
- C. Dielectric Flanges:
- 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. GF Piping Systems: Georg Fischer LLC.
 - 2. Description:
 - a. Standard: ASSE 1079.
 - b. Factory-fabricated, bolted, companion-flange assembly.
 - c. Pressure Rating: 150 psig minimum at 200 deg F.
 - d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

D. Dielectric Nipples:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Anvil International/Smith-Cooper International; Tailwind Capital, LLC.
 - b. Elster Perfection; Honeywell.
 - c. GPT; a division of EnPRO Industries.
 - d. Matco-Norca.
 - e. Precision Plumbing Products.
 - f. Sioux Chief Manufacturing Company, Inc.
2. Description:
 - a. Standard: IAPMO PS 66.
 - b. Electroplated steel nipple, complying with ASTM F1545.
 - c. Pressure Rating: 300 psig at 225 deg F.
 - d. End Connections: Male threaded or grooved.
 - e. Lining: Inert and noncorrosive, propylene.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

- A. Hot-water heating piping, aboveground, NPS 2 and smaller , shall be any of the following:
 1. Type L , drawn-temper copper tubing, wrought-copper fittings, and soldered or pressure-seal joints.
 2. Schedule 40 , Grade B steel pipe; Class 150, malleable-iron fittings; cast-iron flanges and flange fittings; and threaded joints.
 3. CPVC plastic pipe and fittings and solvent-welded joints.
- B. Hot-water heating piping, aboveground, NPS 2-1/2 and larger , shall be any of the following:
 1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
 2. steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
- C. Chilled-water piping, aboveground, NPS 2 and smaller , shall be any of the following:
 1. Type L , drawn-temper copper tubing, wrought-copper fittings, and solderedor pressure-seal joints.
 2. Schedule 40 steel pipe; Class 150, malleable-iron fittings; cast-iron flanges and flange fittings; and threaded joints.
 3. CPVC plastic pipe and fittings and solvent-welded joints.
- D. Chilled-water piping, aboveground, NPS 2-1/2 and larger , shall be any of the following:
 1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
 2. steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints.
- E. Makeup-water piping installed aboveground shall be the following:
 1. Type L , drawn-temper copper tubing, wrought-copper fittings, and soldered joints.

- F. Condensate-Drain Piping, Copper: Type M , drawn-temper copper tubing, wrought-copper fittings, and soldered joints.
- G. Air-Vent Piping:
 - 1. Inlet: Same as service where installed with metal-to-plastic transition fittings for plastic piping systems according to piping manufacturer's written instructions.
 - 2. Outlet: Type K, annealed-temper copper tubing with soldered or flared joints.

3.2 EARTHWORK

- A. Comply with requirements in Section 312000 "Earth Moving" for excavating, trenching, and backfilling.

3.3 INSTALLATION OF PIPING

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- E. Install piping to permit valve servicing.
- F. Install piping at indicated slopes.
- G. Install piping free of sags and bends.
- H. Install fittings for changes in direction and branch connections.
- I. Install piping to allow application of insulation.
- J. Select system components with pressure rating equal to or greater than system operating pressure.
- K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.
- L. Install drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.
- M. Reduce pipe sizes using eccentric reducer fitting installed with level side up.
- N. Install branch connections to mains using tee fittings in main pipe, with the branch connected to the top of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.
- O. Install valves according to the following:
 - 1. Section 230523.11 "Globe Valves for HVAC Piping."

2. Section 230523.12 "Ball Valves for HVAC Piping."
 3. Section 230523.13 "Butterfly Valves for HVAC Piping."
 4. Section 230523.14 "Check Valves for HVAC Piping."
 5. Section 230523.15 "Gate Valves for HVAC Piping."
- P. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.
- Q. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.
- R. Install shutoff valve immediately upstream of each dielectric fitting.
- S. Comply with requirements in Section 230516 "Expansion Fittings and Loops for HVAC Piping" for installation of expansion loops, expansion joints, anchors, and pipe alignment guides.
- T. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for identifying piping.
- U. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- V. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- W. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."
- X. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- Y. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

3.4 JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Soldered Joints: Apply ASTM B813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B32.
- D. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.
- E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.

2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- F. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.
- G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.
- H. Plastic Piping Solvent-Cemented Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:
 1. Comply with ASTM F402 for safe-handling practice of cleaners, primers, and solvent cements.
 2. CPVC Piping: Join according to ASTM D2846/D2846M Appendix.
- I. Grooved Joints: Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness. Use grooved-end fittings and rigid, grooved-end-pipe couplings.
- J. Pressure-Sealed Joints: Use manufacturer-recommended tools and procedure. Leave insertion marks on pipe after assembly.

3.5 INSTALLATION OF DIELECTRIC FITTINGS

- A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.
- B. Dielectric Fittings for NPS 2 and Smaller: Use dielectric unions.
- C. Dielectric Fittings for NPS 2-1/2 to NPS 4 : Use dielectric flanges.
- D. Dielectric Fittings for NPS 5 and Larger: Use dielectric flange kits.

3.6 INSTALLATION OF HANGERS AND SUPPORTS

- A. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Comply with requirements in Section 230529 "Hangers and Supports for HVAC Piping and Equipment" for hangers, supports, and anchor devices.

3.7 TERMINAL EQUIPMENT CONNECTIONS

- A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.
- B. Install control valves in accessible locations close to connected equipment.
- C. Install ports for pressure gauges and thermometers at coil inlet and outlet connections. Comply with requirements in Section 230519 "Meters and Gages for HVAC Piping."

3.8 IDENTIFICATION

- A. Identify system components. Comply with requirements for identification materials and installation in Section 230553 "Identification for HVAC Piping and Equipment."

3.9 FIELD QUALITY CONTROL

- A. Prepare hydronic piping according to ASME B31.9 and as follows:
1. Leave joints, including welds, uninsulated and exposed for examination during test.
 2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
 3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
 4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
 5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.
- B. Perform the following tests on hydronic piping:
1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
 2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
 3. Isolate expansion tanks and determine that hydronic system is full of water.
 4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
 5. After hydrostatic test pressure has been applied for at least 4 hours, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks. No change in pressure is allowed.
 6. Prepare written report of testing.
- C. Perform the following before operating the system:
1. Open manual valves fully.
 2. Inspect pumps for proper rotation.
 3. Set makeup pressure-reducing valves for required system pressure.
 4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
 5. Set temperature controls so all coils are calling for full flow.
 6. Inspect and set operating temperatures of hydronic equipment, such as boilers, chillers, cooling towers, to specified values.
 7. Verify lubrication of motors and bearings.

END OF SECTION 232113

SECTION 232116 - HYDRONIC PIPING SPECIALTIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

- 1. Hydronic specialty valves.
 - 2. Air-control devices.
 - 3. Strainers.
 - 4. Connectors.

- B. Related Requirements:

- 1. Section 230516 "Expansion Fittings and Loops for HVAC Piping" for expansion fittings and loops.
 - 2. Section 230523.11 "Globe Valves for HVAC Piping" for specification and installation requirements for globe valves common to most piping systems.
 - 3. Section 230523.12 "Ball Valves for HVAC Piping" for specification and installation requirements for ball valves common to most piping systems.
 - 4. Section 230523.13 "Butterfly Valves for HVAC Piping" for specification and installation requirements for butterfly valves common to most piping systems.
 - 5. Section 230523.14 "Check Valves for HVAC Piping" for specification and installation requirements for check valves common to most piping systems.
 - 6. Section 230523.15 "Gate Valves for HVAC Piping" for specification and installation requirements for gate valves common to most piping systems.
 - 7. Section 230923.11 "Control Valves" for automatic control valve and sensor specifications, installation requirements, and locations.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product:

- 1. Include construction details and material descriptions for hydronic piping specialties.
 - 2. Include rated capacities, operating characteristics, and furnished specialties and accessories.
 - 3. Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For hydronic piping specialties to include in emergency, operation, and maintenance manuals.

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Differential Pressure Meter: For each type of balancing valve and automatic flow control valve, include flowmeter, probes, hoses, flow charts, and carrying case.

1.6 QUALITY ASSURANCE

- A. Safety Valves and Pressure Vessels: Shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

PART 2 - PRODUCTS

2.1 HYDRONIC SPECIALTY VALVES

- A. Bronze, Calibrated-Orifice, Balancing Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Armstrong Pumps, Inc.
 - b. Bell & Gossett; a Xylem brand.
 - c. Gerand Engineering Co.
 - d. Griswold Controls.
 - e. IMI Flow Design, Inc.
 - f. Taco Comfort Solutions.
 - g. Tour & Andersson; available through Victaulic Company.
 - h. Victaulic Company.
2. Body: Bronze, ball or plug type with calibrated orifice or venturi.
3. Ball: Brass or stainless steel.
4. Plug: Resin.
5. Seat: PTFE.
6. End Connections: Threaded or socket.
7. Pressure Gage Connections: Integral seals for portable differential pressure meter.
8. Handle Style: Lever, with memory stop to retain set position.
9. CWP Rating: Minimum 125 psig.
10. Maximum Operating Temperature: 250 deg F.

- B. Cast-Iron or Steel, Calibrated-Orifice, Balancing Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Armstrong Fluid Technology.
 - b. Bell & Gossett; a Xylem brand.
 - c. Griswold Controls.
 - d. IMI Flow Design, Inc.
 - e. Tour & Andersson; available through Victaulic Company.
 - f. Victaulic Company.
2. Body: Cast-iron or steel body, ball, plug, or globe pattern with calibrated orifice or venturi.
3. Ball: Brass or stainless steel.
4. Stem Seals: EPDM O-rings.

5. Disc: Glass and carbon-filled PTFE.
6. Seat: PTFE.
7. End Connections: Flanged or grooved.
8. Pressure Gage Connections: Integral seals for portable differential pressure meter.
9. Handle Style: Lever, with memory stop to retain set position.
10. CWP Rating: Minimum 125 psig.
11. Maximum Operating Temperature: 250 deg F.

C. Diaphragm-Operated, Pressure-Reducing Valves: ASME labeled.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. NIBCO INC.
 - b. Victaulic Company.
 - c. WATTS.
2. Body: Bronze or brass.
3. Disc: Glass and carbon-filled PTFE.
4. Seat: Brass.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Low inlet-pressure check valve.
8. Inlet Strainer: Removable without system shutdown.
9. Valve Seat and Stem: Noncorrosive.
10. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

D. Diaphragm-Operated Safety Valves: ASME labeled.

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. WATTS.
2. Body: Bronze or brass.
3. Disc: Glass and carbon-filled PTFE.
4. Seat: Brass.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Wetted, Internal Work Parts: Brass and rubber.
8. Inlet Strainer: , removable without system shutdown.
9. Valve Seat and Stem: Noncorrosive.
10. Valve Size, Capacity, and Operating Pressure: Comply with ASME Boiler and Pressure Vessel Code: Section IV, and selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

E. Automatic Flow-Control Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Griswold Controls.
 - b. IMI Flow Design, Inc.
 - c. NIBCO INC.
 - d. Victaulic Company.
2. Body: Brass or ferrous metal.

3. Flow Control Assembly, provide either of the following:
 - a. Piston and Spring Assembly: Corrosion resistant, tamper proof, self-cleaning, and removable.
 - b. Elastomeric Diaphragm and Polyphenylsulfone Orifice Plate: Operating ranges within 2- to 80-psig differential pressure.
4. Combination Assemblies: Include bronze or brass-alloy ball valve.
5. Identification Tag: Marked with zone identification, valve number, and flow rate.
6. Size: Same as pipe in which installed.
7. Performance: Maintain constant flow within plus or minus 10 percent, regardless of system pressure fluctuations.
8. Minimum CWP Rating: 175 psig.
9. Maximum Operating Temperature: 200 deg F.

2.2 AIR-CONTROL DEVICES

A. Manual Air Vents:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Bell & Gossett; a Xylem brand.
 - b. Taco Comfort Solutions.
 - c. WATTS.
2. Body: Bronze.
3. Internal Parts: Nonferrous.
4. Operator: Screwdriver or thumbscrew.
5. Inlet Connection: NPS 1/2.
6. Discharge Connection: NPS 1/8.
7. CWP Rating: 150 psig.
8. Maximum Operating Temperature: 225 deg F.

B. Automatic Air Vents:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Bell & Gossett; a Xylem brand.
 - b. Metraflex Company (The).
 - c. Taco Comfort Solutions.
 - d. WATTS.
2. Body: Bronze or cast iron.
3. Internal Parts: Nonferrous.
4. Operator: Noncorrosive metal float.
5. Inlet Connection: NPS 1/2.
6. Discharge Connection: NPS 1/4.
7. CWP Rating: 150 psig.
8. Maximum Operating Temperature: 240 deg F.

C. Expansion Tanks:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Armstrong Fluid Technology.
 - b. Bell & Gossett; a Xylem brand.
 - c. Taco Comfort Solutions.
 - d. WATTS.
2. Tank: Welded steel, rated for 125-psig working pressure and 375 deg F maximum operating temperature, with taps in bottom of tank for tank fitting and taps in end of tank for gage glass. Tanks shall be factory tested after taps are fabricated and shall be labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
3. Air-Control Tank Fitting: Cast-iron body, copper-plated tube, brass vent tube plug, and stainless-steel ball check, 100-gal. unit only; sized for compression-tank diameter. Provide tank fittings for 125-psig working pressure and 250 deg F maximum operating temperature.
4. Tank Drain Fitting: Brass body, nonferrous internal parts; 125-psig working pressure and 240 deg F maximum operating temperature; constructed to admit air to compression tank, drain water, and close off system.
5. Gage Glass: Full height with dual manual shutoff valves, 3/4-inch- diameter gage glass, and slotted-metal glass guard.

D. Bladder-Type ASME Expansion Tanks:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Bell & Gossett; a Xylem brand.
 - b. Taco Comfort Solutions.
 - c. WATTS.
2. Tank: Welded steel, rated for 125-psig working pressure and 375 deg F maximum operating temperature. Factory test after taps are fabricated and supports installed and are labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
3. Bladder: Securely sealed into tank to separate air charge from system water to maintain required expansion capacity.
4. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.

E. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.

F. Tangential-Type Air Separators:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Bell & Gossett; a Xylem brand.
 - b. Taco Comfort Solutions.
2. Tank: Welded steel; ASME constructed and labeled for 125-psig minimum working pressure and 375 deg F maximum operating temperature.
3. Air Collector Tube: Perforated stainless steel, constructed to direct released air into expansion tank.
4. Tangential Inlet and Outlet Connections: Threaded for NPS 2 and smaller; flanged connections for NPS 2-1/2 and larger.
5. Blowdown Connection: Threaded.
6. Size: Match system flow capacity.

2.3 STRAINERS

A. Y-Pattern Strainers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Metraflex Company (The).
 - b. WATTS.
2. Body: ASTM A126, Class B, cast iron with bolted cover and bottom drain connection.
3. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.
4. Strainer Screen: Stainless-steel, 20 -mesh strainer, or perforated stainless-steel basket.
5. CWP Rating: 125 psig.

2.4 FLEXIBLE CONNECTORS

- A. Flexible connectors as specified in Section 230548 "Vibration and Seismic Controls for HVAC" or 23 05 48.13 "Vibration Controls for HVAC."

PART 3 - EXECUTION

3.1 VALVE APPLICATIONS

- A. Install shutoff-duty valves at each branch connection to supply mains and at supply connection to each piece of equipment.
- B. Install calibrated-orifice, balancing valves at each branch connection to return main.
- C. Install calibrated-orifice, balancing valves in the return pipe of each heating or cooling terminal.
- D. Install check valves at each pump discharge and elsewhere as required to control flow direction.
- E. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install drip-pan elbow on safety-valve outlet and pipe without valves to the outdoors; pipe drain to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.
- F. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

3.2 HYDRONIC SPECIALTIES INSTALLATION

- A. Install manual air vents at high points in piping, at heat-transfer coils, and elsewhere as required for system air venting.
- B. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Install manual vents at heat-transfer coils and elsewhere as required for air venting.
- C. Install piping from boiler air outlet, air separator, or air purger to expansion tank with a 2 percent upward slope toward tank.

- D. Install tangential air separator in pump suction. Install blowdown piping with gate or full-port ball valve; extend full size to nearest floor drain.
- E. Install expansion tanks on the floor. Vent and purge air from hydronic system, and ensure that tank is properly charged with air to suit system Project requirements.

END OF SECTION 232116

SECTION 232123 - HYDRONIC PUMPS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Close-coupled, in-line centrifugal pumps.
 - 2. Close-coupled, end-suction centrifugal pumps.

1.3 DEFINITIONS

- A. ECM: Electronically commutated motor.
- B. EPDM: Ethylene propylene diene monomer.
- C. EPR: Ethylene propylene rubber.
- D. FKM: Fluoroelastomer polymer.
- E. HI: Hydraulic Institute.
- F. NBR: Nitrile rubber or Buna-N.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of pump.
 - 1. Include certified performance curves and rated capacities, operating characteristics, furnished specialties, final impeller dimensions, and accessories for each type of product indicated.
 - 2. Indicate pump's operating point on curves.
- B. Shop Drawings: For each pump.
 - 1. Show pump layout and connections.
 - 2. Include setting drawings with templates for installing foundation and anchor bolts and other anchorages.
 - 3. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.
- B. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For pumps to include in emergency, operation, and maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Mechanical Seals: One mechanical seal(s) for each pump.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Armstrong Pumps, Inc.
 - 2. Aurora Pump; Pentair Ltd.
 - 3. Bell & Gossett, a Xylem Brand.
 - 4. Crane Pumps & Systems.
 - 5. Grundfos Pumps Corporation.
 - 6. ITT Corporation.
 - 7. Mepco, LLC.
 - 8. PACO Pumps; Grundfos Pumps Corporation, USA.
 - 9. Patterson Pump Company; a Gorman-Rupp company.
 - 10. Peerless Pump Company.
- B. Source Limitations: Obtain pumps from single source from single manufacturer.
- C. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically.

D. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gauge tappings at inlet and outlet , replaceable bronze wear rings, and threaded companion-flange connections.
2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Impeller radius shall not exceed 85% of the pump's cutwater radius. For constant-speed pumps, trim impeller to match specified performance.
3. Pump Shaft Sleeve: Bronze Type 304 stainless steel.
4. Pump Stub Shaft: Type 304 Type 316 stainless steel.
5. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and NBR EPDM FKM rubber bellows and gasket. Include water slinger on shaft between motor and seal.
6. Seal Flushing: Flush, cool, and lubricate pump seal by directing pump discharge water to flow over the seal.

E. Shaft Coupling: Rigid, axially-split spacer coupling to allow service of pump seal without disturbing pump or motor.

F. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Enclosure : 1. Motors shall be dripproof, unless otherwise specified herein or indicated on the Drawings.
2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. Variable-speed motor.

2.3 CLOSE-COUPLED, END-SUCTION CENTRIFUGAL PUMPS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Armstrong Pumps, Inc.
2. Aurora Pump; Pentair Ltd.
3. Bell & Gossett, a Xylem Brand
4. ITT Corporation.
5. Patterson Pump Company; a Gorman-Rupp company.
6. Thrush Co. Inc.

B. Source Limitations: Obtain pumps from single source from single manufacturer.

C. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally.

D. Pump Construction:

1. Casing: Radially split, cast iron, with replaceable bronze wear rings, drain plug at bottom and air vent at top of volute, threaded gauge tappings at inlet and outlet, and flanged connections.
2. Impeller: ASTM B584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. Impeller radius shall not exceed 85% of the pump's cutwater radius. For constant-speed pumps, trim impeller to match specified performance.

3. Pump Shaft Sleeve: Bronze Type 304 stainless steel.
4. Pump Stub Shaft: Type 304 Type 316 stainless steel.
5. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless steel spring, and NBR EPDM FKM bellows and gasket. Include water slinger on shaft between motor and seal.

E. Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

1. Enclosure: Motors shall be dripproof, unless otherwise specified herein or indicated on the Drawings.
2. NEMA Premium Efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
5. Variable-speed motor.

F. Capacities and Characteristics:

1. Capacity: See Drawings.

2.4 PUMP SPECIALTY FITTINGS

A. Suction Diffuser:

1. Angle pattern.
2. 175-psig pressure rating, cast ductile-iron body and end cap, pump-inlet fitting.
3. Bronze 16-mesh wire startup and Type 304 stainless steel permanent strainers with 3/16-inch.
4. Type 304 stainless steel straightening vanes.
5. Drain plug.
6. Factory-fabricated support.

2.5 ELECTRONICALLY COMMUTATED MOTOR (ECM)

A. Provide pumps so they are specified or scheduled with ECM.

1. Synchronous, constant torque, ECM with permanent magnet rotor. Rotor magnets to be time-stable, nontoxic ceramic magnets (Sr-Fe).
2. Driven by a frequency converter with an integrated power factor correction filter. Conventional induction motors will not be acceptable.
3. Each motor with an integrated variable-frequency drive, tested as one unit by manufacturer.
4. Motor speed adjustable over full range from 0 rpm to maximum scheduled speed.
5. Variable motor speed to be controlled by a 0- to 10 V-dc or 4- to 20-mA input.
6. Integrated motor protection verified by UL to protect the pump against over-/undervoltage, overtemperature of motor and/or electronics, overcurrent, locked rotor, and dry run (no-load condition).

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine equipment foundations and anchor-bolt locations for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.
- C. Examine foundations and inertia bases for suitable conditions where pumps will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PUMP INSTALLATION

- A. Comply with HI 1.4 and HI 2.4.
- B. Install pumps to provide access for periodic maintenance including removing motors, impellers, couplings, and accessories.
- C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.
- D. Automatic Condensate Pump Units: Install units for collecting condensate and extend to open drain.
- E. Equipment Mounting:
 - 1. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 2. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- F. Equipment Mounting: Install in-line pumps with continuous-thread hanger rods and spring hangers of size required to support weight of in-line pumps.
 - 1. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 2. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

3.3 ALIGNMENT

- A. Engage a factory-authorized service representative to perform alignment service.
- B. Comply with requirements in HI standards for alignment of pump and motor shaft. Add shims to the motor feet and bolt motor to base frame. Do not use grout between motor feet and base frame.
- C. Comply with pump and coupling manufacturers' written instructions.

- D. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with nonshrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

3.4 PIPING CONNECTIONS

- A. Comply with requirements for piping specified in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to pump, allow space for service and maintenance.
- C. Connect piping to pumps. Install valves that are same size as piping connected to pumps.
- D. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles.
- E. Install suction diffuser and shutoff valve on suction side of pumps.
 - 1. Use startup strainer for initial system startup. Install permanent strainer element before turnover of system to Owner.
- F. Install pressure gauges on pump suction and discharge or at integral pressure-gauge tapping, or install single gauge with multiple-input selector valve.
- G. Install check valve on each condensate pump unit discharge unless unit has a factory-installed check valve.

3.5 ELECTRICAL CONNECTIONS

- A. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."
- C. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.
- D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.
 - 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
 - 2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.6 CONTROL CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.
- B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

3.7 STARTUP SERVICE

A. Perform startup service.

1. Complete installation and startup checks in accordance with manufacturer's written instructions.
2. Check piping connections for tightness.
3. Clean strainers on suction piping. Use startup strainer for initial startup.
4. Perform the following startup checks for each pump before starting:
 - a. Verify bearing lubrication.
 - b. Verify that pump is free to rotate by hand and that pump for handling hot liquid is free to rotate with pump hot and cold. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
 - c. Verify that pump is rotating in correct direction.
5. Prime pump by opening suction valves and closing drains, and prepare pump for operation.
6. Start motor.
7. Open discharge valve slowly.

3.8 FIELD QUALITY CONTROL

- A. Testing Agency: a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.
- C. Hydronic pumps will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.9 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps.

END OF SECTION 232123

SECTION 232300 - REFRIGERANT PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Copper tube and fittings.
 - 2. Refrigerants.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of valve, refrigerant piping, and piping specialty.
 - 1. Include pressure drop, based on manufacturer's test data, for the following:
 - a. Pressure-regulating valves.
- B. Sustainable Design Submittals:
 - 1. Refrigerant: Product Data for refrigerants, indicating compliance with refrigerant management practices.
- C. Shop Drawings:
 - 1. Show layout of refrigerant piping and specialties, including pipe, tube, and fitting sizes; flow capacities; valve arrangements and locations; slopes of horizontal runs; oil traps; double risers; wall and floor penetrations; and equipment connection details.
 - 2. Show piping size and piping layout, including oil traps, double risers, specialties, and pipe and tube sizes to accommodate, as a minimum, equipment provided, elevation difference between compressor and evaporator, and length of piping to ensure proper operation and compliance with warranties of connected equipment.
 - 3. Show interface and spatial relationships between piping and equipment.
 - 4. Shop Drawing Scale: 1/4 inch equals 1 foot.

1.4 INFORMATIONAL SUBMITTALS

- A. Welding certificates.
- B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For refrigerant valves and piping specialties to include in maintenance manuals.

1.6 QUALITY ASSURANCE

- A. Welding Qualifications: Qualify procedures and personnel according to 2010 ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
- B. Comply with ASHRAE 15, "Safety Code for Refrigeration Systems."
- C. Comply with ASME B31.5, "Refrigeration Piping and Heat Transfer Components."

1.7 PRODUCT STORAGE AND HANDLING

- A. Store piping with end caps in place to ensure that piping interior and exterior are clean when installed.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Line Test Pressure for Refrigerant R-134a:
 - 1. Suction Lines for Air-Conditioning Applications: 115 psig.
 - 2. Suction Lines for Heat-Pump Applications: 225 psig.
- B. Line Test Pressure for Refrigerant R-410A:
 - 1. Suction Lines for Air-Conditioning Applications: 300 psig.
 - 2. Suction Lines for Heat-Pump Applications: 535 psig.

2.2 COPPER TUBE AND FITTINGS

- A. Copper Tube: ASTM B 88, Type K or L.
- B. Wrought-Copper Fittings, Solder-Joint: ASME B16.22.
- C. Wrought-Copper Fittings, Brazed-Joint: ASME B16.50.
- D. Wrought-Copper Unions: ASME B16.22.
- E. Solder Filler Metals: ASTM B 32. Use 95-5 tin antimony or alloy HB solder to join copper socket fittings on copper pipe.
- F. Brazing Filler Metals: AWS A5.8/A5.8M.

2.3 STEEL PIPE AND FITTINGS

- A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; type, grade, and wall thickness as selected in piping application articles.

2.4 REFRIGERANTS

- A. ASHRAE 34, R-134a: Tetrafluoroethane.

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Arkema Inc.
 - b. DuPont Fluorochemicals Div.
 - c. Genetron Refrigerants; Honeywell International Inc.
 - d. Mexichem Fluor Inc.

- B. ASHRAE 34, R-410A: Pentafluoroethane/Difluoromethane.

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Arkema Inc.
 - b. DuPont Fluorochemicals Div.
 - c. Genetron Refrigerants; Honeywell International Inc.
 - d. Mexichem Fluor Inc.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS FOR REFRIGERANT R-134a

- A. Suction Lines NPS 1-1/2 and Smaller for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.
- B. Safety-Relief-Valve Discharge Piping, Copper: Copper, Type ACR , drawn-temper tubing and wrought-copper fittings with soldered joints.

3.2 PIPING APPLICATIONS FOR REFRIGERANT R-410A

- A. Suction Lines NPS 1-1/2 and Smaller for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.
- B. Safety-Relief-Valve Discharge Piping:
 - 1. Copper, Type ACR , annealed- or drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.

3.3 VALVE AND SPECIALTY APPLICATIONS

- A. Install valves in suction and discharge lines of compressor.
- B. Except as otherwise indicated, install valves on inlet and outlet side of filter dryers.

- C. Install a full-size, three-valve bypass around filter dryers.
- D. Install moisture/liquid indicators in liquid line at the inlet of the thermostatic expansion valve or at the inlet of the evaporator coil capillary tube.
- E. Install flexible connectors at compressors.
- F. Provide refrigerant locking caps on refrigerant charging ports that are located outdoors unless otherwise protected from unauthorized access by a means acceptable to the authority having jurisdiction.

3.4 INSTALLATION OF PIPING, GENERAL

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems; indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Shop Drawings.
- B. Install refrigerant piping according to ASHRAE 15.
- C. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- F. Install piping adjacent to machines to allow service and maintenance.
- G. Install piping free of sags and bends.
- H. Install fittings for changes in direction and branch connections.
- I. Select system components with pressure rating equal to or greater than system operating pressure.
- J. Refer to Section 230923 "Direct Digital Control (DDC) System for HVAC" and Section 230993.11 "Sequence of Operations for HVAC DDC" for solenoid valve controllers, control wiring, and sequence of operation.
- K. Install piping as short and direct as possible, with a minimum number of joints, elbows, and fittings.
- L. Arrange piping to allow inspection and service of refrigeration equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels as specified in Section 083113 "Access Doors and Frames" if valves or equipment requiring maintenance is concealed behind finished surfaces.
- M. Install refrigerant piping in protective conduit where installed belowground.
- N. Install refrigerant piping in rigid or flexible conduit in locations where exposed to mechanical injury.
- O. Slope refrigerant piping as follows:
 - 1. Install horizontal hot-gas discharge piping with a uniform slope downward away from compressor.
 - 2. Install horizontal suction lines with a uniform slope downward to compressor.

3. Install traps and double risers to entrain oil in vertical runs.
 4. Liquid lines may be installed level.
- P. When brazing or soldering, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion-valve bulb.
- Q. Before installation of steel refrigerant piping, clean pipe and fittings using the following procedures:
1. Shot blast the interior of piping.
 2. Remove coarse particles of dirt and dust by drawing a clean, lintless cloth through tubing by means of a wire or electrician's tape.
 3. Draw a clean, lintless cloth saturated with trichloroethylene through the tube or pipe. Continue this procedure until cloth is not discolored by dirt.
 4. Draw a clean, lintless cloth, saturated with compressor oil, squeezed dry, through the tube or pipe to remove remaining lint. Inspect tube or pipe visually for remaining dirt and lint.
 5. Finally, draw a clean, dry, lintless cloth through the tube or pipe.
 6. Safety-relief-valve discharge piping is not required to be cleaned but is required to be open to allow unrestricted flow.
- R. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation.
- S. Identify refrigerant piping and valves according to Section 230553 "Identification for HVAC Piping and Equipment."
- T. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- U. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517 "Sleeves and Sleeve Seals for HVAC Piping."
- V. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230518 "Escutcheons for HVAC Piping."

3.5 PIPE JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Fill pipe and fittings with an inert gas (nitrogen or carbon dioxide), during brazing or welding, to prevent scale formation.
- D. Soldered Joints: Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook."
- E. Brazed Joints: Construct joints according to AWS's "Braze Handbook," Chapter "Pipe and Tube."
1. Use Type BCuP (copper-phosphorus) alloy for joining copper socket fittings with copper pipe.
 2. Use Type BAg (cadmium-free silver) alloy for joining copper with bronze or steel.

- F. Threaded Joints: Thread steel pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and to restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads unless dry-seal threading is specified.
 - 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- G. Steel pipe can be threaded, but threaded joints must be seal brazed or seal welded.
- H. Welded Joints: Construct joints according to AWS D10.12M/D10.12.
- I. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

3.6 INSTALLATION OF HANGERS AND SUPPORTS

- A. Comply with requirements for seismic restraints in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Comply with Section 230529 "Hangers and Supports for HVAC Piping and Equipment" for hangers, supports, and anchor devices.
- C. Install the following pipe attachments:
 - 1. Adjustable steel clevis hangers for individual horizontal runs less than 20 feet long.
 - 2. Roller hangers and spring hangers for individual horizontal runs 20 feet or longer.
 - 3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
 - 4. Spring hangers to support vertical runs.
 - 5. Copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.
- D. Install hangers for copper tubing, with maximum horizontal spacing and minimum rod diameters, to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.
- E. Support horizontal piping within 12 inches of each fitting.
- F. Support vertical runs of copper tubing to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

3.7 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
 - 1. Comply with ASME B31.5, Chapter VI.
 - 2. Test refrigerant piping, specialties, and receivers. Isolate compressor, condenser, evaporator, and safety devices from test pressure if they are not rated above the test pressure.
 - 3. Test high- and low-pressure side piping of each system separately at not less than the pressures indicated in "Performance Requirements" Article.
 - a. Fill system with nitrogen to the required test pressure.

- b. System shall maintain test pressure at the manifold gage throughout duration of test.
- c. Test joints and fittings with electronic leak detector or by brushing a small amount of soap and glycerin solution over joints.
- d. Remake leaking joints using new materials, and retest until satisfactory results are achieved.

- B. Prepare test and inspection reports.

3.8 SYSTEM CHARGING

- A. Charge system using the following procedures:
 - 1. Install core in filter dryers after leak test but before evacuation.
 - 2. Evacuate entire refrigerant system with a vacuum pump to 500 micrometers. If vacuum holds for 12 hours, system is ready for charging.
 - 3. Break vacuum with refrigerant gas, allowing pressure to build up to 2 psig.
 - 4. Charge system with a new filter-dryer core in charging line.

3.9 ADJUSTING

- A. Adjust high- and low-pressure switch settings to avoid short cycling in response to fluctuating suction pressure.
- B. Adjust set-point temperature of air-conditioning or chilled-water controllers to the system design temperature.
- C. Perform the following adjustments before operating the refrigeration system, according to manufacturer's written instructions:
 - 1. Open shutoff valves in condenser water circuit.
 - 2. Verify that compressor oil level is correct.
 - 3. Open compressor suction and discharge valves.
 - 4. Open refrigerant valves except bypass valves that are used for other purposes.
 - 5. Check open compressor-motor alignment and verify lubrication for motors and bearings.
- D. Replace core of replaceable filter dryer after system has been adjusted and after design flow rates and pressures are established.

END OF SECTION 232300

SECTION 232500 - HVAC WATER TREATMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes the following HVAC water-treatment systems:
 - 1. Manual and automatic chemical-feed equipment and controls.
 - 2. Chemical-treatment test equipment.
 - 3. Chemicals.
 - 4. TDS controllers.
 - 5. TSS controllers.
 - 6. Water-filtration equipment.

1.3 DEFINITIONS

- A. EEPROM: Electrically erasable, programmable read-only memory.
- B. PPM: Parts per million.
- C. RO: Reverse osmosis.
- D. TDS: Total dissolved solids consist of salts and other materials that combine with water as a solution.
- E. TSS: Total suspended solids include both organic and inorganic solids that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, operating characteristics, and furnished specialties and accessories for the following products:
 - 1. Bypass feeders.
 - 2. Water meters.
 - 3. Inhibitor injection timers.
 - 4. pH controllers.
 - 5. TDS controllers.
 - 6. TSS controllers.
 - 7. Biocide feeder timers.
 - 8. Chemical solution tanks.
 - 9. Injection pumps.
 - 10. Ozone generators.
 - 11. UV-irradiation units.

12. Chemical test equipment.
13. Chemical material safety data sheets.
14. Centrifugal separators.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For chemical-treatment equipment and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Water-Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.
- C. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.
- D. Water Analysis: Illustrate water quality available at Project site.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sensors, injection pumps, and controllers to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

- A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider, capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

PART 2 - PRODUCTS

2.1 HVAC WATER-TREATMENT MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Anderson Chemical Company.
 2. Aqua-Chem, Inc.
 3. Barclay Water Management, Inc.
 4. Boland Trane Services.
 5. Cascade Water Services, Inc.
 6. Earthwise Environmental Inc.
 7. Nalco; an Ecolab company.
 8. Watcon, Inc.

2.2 PERFORMANCE REQUIREMENTS

- A. Provide all hardware, chemicals, and other material necessary to maintain HVAC water quality in all systems as indicated in this Specification. Water quality for HVAC systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or to the environment.
- B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.
- C. Closed hydronic systems, including hot-water heating below 250 deg F, chilled water shall have the following water qualities:
 - 1. pH: Maintain a value within 9.0-10.5.
 - 2. Alkalinity: Maintain a value within 500-1500 ppm as NaNO₂ (sodium nitrate)
 - 3. Steel Corrosion Inhibitors: Provide sufficient inhibitors to limit mild steel corrosion. Maintain soluble iron concentrations at or below .25 ppm.
 - 4. Yellow Metal Corrosion Inhibitor: Provide sufficient copper and brass corrosion inhibitors to limit copper corrosion. Maintain soluble copper concentrations at or below .25 ppm.
 - 5. Scale Control: Provide softened water for initial fill and makeup. Where softened water is not used, provide sufficient scale inhibitors to prevent formation of scale and maintain all scale-forming material in solution.
 - 6. Dispersants: Provide sufficient dispersants to prevent sedimentation of fine particulate matter.

2.3 MANUAL CHEMICAL-FEED EQUIPMENT

- A. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum 3-1/2-inch fill opening in the top, and NPS 3/4 bottom inlet and top side outlet. Provide quarter- turn or threaded fill cap with gasket seal and diaphragm arranged to lock the top onto the feeder when exposed to system pressure in the vessel. Provide a NPS 3/4 IN quarter-turn valve on inlet and outlet.
 - 1. Capacity: 5 gal.
 - 2. Minimum Working Pressure: 175 psig.

2.4 AUTOMATIC CHEMICAL-FEED EQUIPMENT

- A. Water Meter, Turbine Type, Flanged:
 - 1. AWWA C701, turbine-type, totalization meter.
 - 2. Body: Bronze.
 - 3. Minimum Working-Pressure Rating: 150 psig.
 - 4. Maximum Pressure Loss at Design Flow: 3 psig.
 - 5. Registration: Gallons or cubic feet.
 - 6. End Connections: Flanged.
 - 7. Controls: Flow-control switch with normally open contacts, rated for maximum 10 A, 250-V ac, that will momentarily close at adjustable increments of total flow.
 - 8. Provide and electronic or digital interface for flow rate indication at central workstation compatible with DDC system, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC." Low-voltage signal must be capable of transmitting 1000 feet.
 - 9. All electrical components, devices, and accessories must be listed and labeled as defined in NFPA 70, by a qualified testing agency, and must be marked for intended location and application.

B. Inhibitor Injection Timers:

1. Microprocessor-based controller with digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."
2. Programmable timers with infinite adjustment over full range, mounted in cabinet with hand-off-auto switches and status lights.
3. Test switch.
4. Hand-off-auto switch for chemical pump.
5. Illuminated legend to indicate feed when pump is activated.
6. Programmable lockout timer with indicator light. Lockout timer to deactivate the pump and activate alarm circuits.
7. Digital display makeup totalizer to measure amount of makeup and bleed-off water from two water meter inputs.

C. pH Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 14 units. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal pH indication.
5. High or low-pH-alarm-light trip points, field adjustable; with silence switch.
6. Hand-off-auto switch for acid pump.
7. Internal adjustable hysteresis or deadband.

D. TDS Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 5000 micromhos. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal conductance indication.
5. High- or low-conductance-alarm-light trip points, field adjustable; with silence switch.
6. Hand-off-auto switch for solenoid bleed-off valve.
7. Bleed-off valve activated indication.
8. Internal adjustable hysteresis or deadband.
9. Bleed Valves:
 - a. Cooling Systems: Forged-brass body, globe pattern, general-purpose solenoid with continuous-duty coil, or motorized valve.
 - b. Steam Boilers: Motorized ball valve, steel body, and TFE seats and seals.

E. TSS Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from 0.001 mg/L to 50 g/L. Incorporate solid-state integrated circuits and digital display in NEMA 250, Type 4X enclosure. Interface for start/stop and status indication at central workstation, as described in Section 230923 "Direct Digital Control (DDC) System for HVAC."
2. Forms of digital communication: MODBUS RS-232 MODBUS RS-485 Profibus DP.
3. Digital display and touch pad for input.
4. Sensor probe adaptable to sample stream manifold.

5. High- or low-value-alarm-light trip points, field adjustable; with silence switch.
6. Hand-off-auto switch for solenoid bleed-off valve.
7. Bleed-off valve activated indication.
8. Internal adjustable hysteresis or deadband.

F. Chemical Solution Tanks:

1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: 50 gal.

G. Chemical Solution Injection Pumps:

1. Self-priming, positive displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.
5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
6. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

H. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints, except ASTM A269/A269M, Type 304 stainless steel for steam boiler injection assemblies.

I. Injection Assembly:

1. Quill: Minimum NPS 1/2 with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: Two-piece stainless steel, as described in "Stainless Steel Pipes and Fittings" Article; selected to fit quill.
3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum 600 psig at 200 deg F.

2.5 CHEMICAL-TREATMENT TEST EQUIPMENT

A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounted cabinet for testing pH, TSS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers; and oxidizing biocide test for open cooling systems.

B. Sample Cooler:

1. Tube: Sample.
 - a. Size: NPS 1/4 tubing.
 - b. Material: ASTM A666, Type 316 stainless steel.
 - c. Pressure Rating: Minimum 2000 psig.
 - d. Temperature Rating: Minimum 850 deg F.

2. Shell: Cooling water.
 - a. Material: ASTM A666, Type 304 stainless steel.
 - b. Pressure Rating: Minimum 250 psig.
 - c. Temperature Rating: Minimum 450 deg F.

3. Capacities and Characteristics:

- a. Tube: Sample.
 - 1) Flow Rate: 0.25 gpm.
 - 2) Entering Temperature: 400 deg F.
 - 3) Leaving Temperature: 88 deg F.
 - 4) Pressure Loss: 6.5 psig.
- b. Shell: Cooling water.
 - 1) Flow Rate: 3 gpm.
 - 2) Entering Temperature: 70 deg F.
 - 3) Pressure Loss: 1.0 psig.

- C. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.

1. Two -station rack for closed-loop systems.

2.6 CHEMICALS

- A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment and that can attain water quality specified in "Performance Requirements" Article.
- B. Chemicals for direct steam injection humidification and for steam used in direct contact with food to be FDA approved and safe for these uses.
- C. Water Softener Chemicals:
 1. Mineral: High-capacity, sulfonated-polystyrene ion-exchange resin that is stable over entire pH range, with good resistance to bead fracture from attrition or shock. Resin exchange capacity minimum **<Insert>** grains/cu. ft.> of calcium carbonate of resin when regenerated with **<Insert lb>** of salt.
 2. Salt for Brine Tanks: High-purity sodium chloride, free of dirt and foreign material. Rock and granulated forms are unacceptable.

PART 3 - EXECUTION

3.1 WATER ANALYSIS

- A. Perform an analysis of supply water to determine quality of water available at Project site.

3.2 INSTALLATION

- A. Install chemical-application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units, so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate. Install all chemical application equipment within a spill-containment area without floor drains.
- B. Install seismic restraints for equipment and floor-mounting accessories, and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Install water-testing equipment on wall near water-chemical-application equipment.
- D. Install interconnecting control wiring for chemical-treatment controls and sensors.
- E. Mount sensors and injectors in piping circuits.
- F. Bypass Feeders: Install in closed hydronic systems, including hot-water heating, chilled water, and equip with the following:
 - 1. Install bypass feeder in a bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 - 2. Install water meter in makeup-water supply.
 - 3. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 - 4. Install a gate or full-port ball isolation valves on inlet, outlet, and drain below feeder inlet.
 - 5. Install a swing check on inlet after the isolation valve.
- G. Install automatic fluid make-up equipment for glycol water system and include the following:
 - 1. Chemical solution tanks.
 - 2. Chemical solution injection pumps.
 - 3. Water meter in makeup supply to system.
 - 4. Pressure switch to operate injection pump as necessary to maintain glycol system pressure.
- H. Install automatic chemical-feed equipment for steam boiler and steam condensate systems and include the following:
 - 1. Install makeup-water softener.
 - 2. Install water meter in makeup-water supply.
 - 3. Install inhibitor injection pumps and solution tanks with injection-timer-sensing contacts in water meter.
 - a. Pumps shall operate for timed interval when contacts close at water meter in makeup-water supply connection.
 - 4. Install test equipment and furnish test-kit to Owner.
 - 5. Install RO unit for makeup water.
 - 6. Install TDS controller with sensor and bleed valves.
 - a. Bleed valves to cycle, to maintain maximum TDS concentration.
 - 7. Install TSS controller with sensor and bleed valves.
 - a. Bleed valves to cycle, to maintain maximum TSS concentration.

8. Install inhibitor injection timer with injection pumps and solution tanks.
 - a. Pumps shall operate for timed interval on contact closure at water meter in makeup-water supply connection. Injection pump shall discharge into main steam supply header.
- I. Install automatic chemical-feed equipment for open condenser water and include the following:
 1. Install water meter in makeup-water supply.
 2. Install inhibitor injection pumps and solution tanks with injection-timer-sensing contacts in water meter.
 - a. Pumps shall operate for timed interval on contact closure at water meter in makeup-water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.
 3. Install test equipment, and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 4. Install TDS controller with sensor and bleed valves.
 - a. Bleed valves to cycle, to maintain maximum TDS concentration.
 5. Install TSS controller with sensor and bleed valves.
 - a. Bleed valves to cycle, to maintain maximum TSS concentration.
 6. Install pH sensor and controller with injection pumps and solution tanks.
 - a. Injector pumps shall operate to maintain required pH.
 7. Install biocide feeder alternating timer with two sets of injection pumps and solution tanks.
 - a. Injection pumps shall operate to feed biocide on an alternating basis.
 8. Install ozone generator with diffusers in condenser-water piping.
 - a. Ozone generator shall operate continuously with condenser-water flow.
 9. Install UV-irradiation lamps in condenser-water piping.
 - a. UV lights shall operate continuously with condenser-water flow.

3.3 WATER SOFTENER INSTALLATION

- A. Install water softener equipment on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units, so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
- B. Install seismic restraints for tanks and floor-mounting accessories, and anchor to building structure. See Section 230548 "Vibration and Seismic Controls for HVAC" for seismic restraints.
- C. Install brine lines and fittings furnished by equipment manufacturer but not factory installed.
- D. Prepare mineral-tank distribution system and underbed for minerals, and place specified mineral into mineral tanks.

- E. Install water-testing sets on wall adjacent to water softeners.

3.4 PIPING CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to equipment, allow space for service and maintenance.
- C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Section 232113 "Hydronic Piping."
- D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Section 230523.11 "Globe Valves for HVAC Piping," Section 230523.12 "Ball Valves for HVAC Piping," Section 230523.13 "Butterfly Valves for HVAC Piping," and Section 230523.15 "Gate Valves for HVAC Piping."
- E. See Section 221119 "Domestic Water Piping Specialties" for backflow preventers required in makeup-water connections to potable-water systems.

3.5 ELECTRICAL CONNECTIONS

- A. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.
- B. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."
- C. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.6 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Tests and Inspections:
 - 1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
 - 2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
 - 3. Place HVAC water-treatment system into operation, and calibrate controls during the preliminary phase of HVAC system's startup procedures.
 - 4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
 - 5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
 - 6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
 - 7. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.

8. Repair leaks and defects with new materials, and retest piping until no leaks exist.
- C. Equipment will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.
- E. Sample boiler water at one-week intervals after boiler startup for a period of five weeks, and prepare test report, advising Owner of changes necessary to adhere to "Performance Requirements" Article for each required characteristic. Sample boiler water at four -week intervals following the testing noted above to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section.
- F. At four -week intervals following Substantial Completion, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis, advising Owner of changes necessary to adhere to "Performance Requirements" Article.
- G. Comply with ASTM D3370 and with the following standards:
 1. Silica: ASTM D859.
 2. Steam System: ASTM D1066.
 3. Acidity and Alkalinity: ASTM D1067.
 4. Iron: ASTM D1068.
 5. Water Hardness: ASTM D1126.

3.7 MAINTENANCE SERVICE

- A. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above, to inhibit corrosion, scale formation, and biological growth for cooling, chilled-water piping heating, hot-water piping and equipment. Services and chemicals shall be provided for a period of one year from date of Substantial Completion and shall include the following:
 1. Initial water analysis and HVAC water-treatment recommendations.
 2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
 3. Periodic field service and consultation.
 4. Customer report charts and log sheets.
 5. Laboratory technical analysis.
 6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.
- B. Training: Provide a "how-to-use" self-contained breathing apparatus video that details exact operating procedures of equipment. When training is complete, turn over video to Owner for future use.

END OF SECTION 232500

SECTION 233113 - METAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

- 1. Single-wall rectangular ducts and fittings.
- 2. Single-wall round ducts and fittings.
- 3. Sheet metal materials.
- 4. Sealants and gaskets.
- 5. Hangers and supports.

- B. Related Sections:

- 1. Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
- 2. Section 233119 "HVAC Casings" for factory- and field-fabricated casings for mechanical equipment.
- 3. Section 233300 "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.

1.3 DEFINITIONS

- A. OSHPD: Office of Statewide Health Planning and Development (State of California).

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of the following products:

- 1. Liners and adhesives.
- 2. Sealants and gaskets.

- B. Shop Drawings:

- 1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
- 2. Factory- and shop-fabricated ducts and fittings.
- 3. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
- 4. Elevation of top and bottom of ducts.
- 5. Dimensions of duct runs from building grid lines.
- 6. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: A single set of plans or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.

1.6 QUALITY ASSURANCE

- A. Air conditioning systems shall conform to the following:

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Airstream Surfaces: Surfaces in contact with airstream shall comply with requirements in ASHRAE 62.1.
- B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment," and Section 7 - "Construction and System Startup."
- C. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
- D. Duct Dimensions: Unless otherwise indicated, all duct dimensions indicated on Drawings are inside clear dimensions and do not include insulation or duct wall thickness.

2.2 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

- A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.
 - 1. Construct ducts of galvanized sheet steel unless otherwise indicated.
- B. Transverse Joints: Fabricate joints in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - 1. For ducts with longest side less than 36 inches, select joint types in accordance with Figure 2-1.
 - 2. For ducts with longest side 36 inches or greater, use flange joint connector Type T-22, T-24, T-24A, T-25a, or T-25b. Factory-fabricated flanged duct connection system may be used if submitted and approved by engineer of record.
- C. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 SINGLE-WALL ROUND DUCTS AND FITTINGS

- A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.
 - 1. Construct ducts of galvanized sheet steel unless otherwise indicated.
- B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).
- C. Transverse Joints: Select joint types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - 1. Transverse Joints in Ducts Larger Than 60 Inches in Diameter: Flanged.
- D. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - 1. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
 - 2. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.
- E. Tees and Laterals: Select types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.4 SHEET METAL MATERIALS

- A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
- B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
 - 1. Galvanized Coating Designation: G60.
 - 2. Finishes for Surfaces Exposed to View: Mill phosphatized.
- C. Carbon-Steel Sheets: Comply with ASTM A 1008/A 1008M, with oiled, matte finish for exposed ducts.
- D. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316, as indicated in "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in "Duct Schedule" Article.
- E. Aluminum Sheets: Comply with ASTM B 209 Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.

- F. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.
 - 1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.
- G. Tie Rods: Galvanized steel, 1/4-inch- minimum diameter for lengths 36 inches or less; 3/8-inch- minimum diameter for lengths longer than 36 inches.

2.5 SEALANT AND GASKETS

- A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested in accordance with UL 723; certified by an NRTL.
- B. Water-Based Joint and Seam Sealant:
 - 1. Application Method: Brush on.
 - 2. Solids Content: Minimum 65 percent.
 - 3. Shore A Hardness: Minimum 20.
 - 4. Water resistant.
 - 5. Mold and mildew resistant.
 - 6. VOC: Maximum 75 g/L (less water).
 - 7. Maximum Static-Pressure Class: 10 inch wg, positive and negative.
 - 8. Service: Indoor or outdoor.
 - 9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

2.6 HANGERS AND SUPPORTS

- A. Hanger Rods for Noncorrosive Environments: Galvanized-steel rods and nuts.
- B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
- C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."
- D. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.
- E. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.
- F. Steel Cable End Connections: Galvanized-steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
- G. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
- H. Trapeze and Riser Supports:
 - 1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
 - 2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.
 - 3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and coordination drawings.
- B. Install ducts in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.
- C. Install ducts in maximum practical lengths with fewest possible joints.
- D. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.
- E. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.
- F. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
- G. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.
- H. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.
- I. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.
- J. Install fire , combination fire/smoke, and smoke dampers where indicated on Drawings and as required by code, and by local authorities having jurisdiction. Comply with requirements in Section 233300 "Air Duct Accessories" for fire and smoke dampers and specific installation requirements of the damper UL listing.
- K. Install heating coils, cooling coils, air filters, dampers, and all other duct-mounted accessories in air ducts where indicated on Drawings.
- L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials both before and after installation. Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."
- M. Elbows: Use long-radius elbows wherever they fit.
 - 1. Fabricate 90-degree rectangular mitered elbows to include turning vanes.
 - 2. Fabricate 90-degree round elbows with a minimum of three segments for 12 inches and smaller and a minimum of five segments for 14 inches and larger.
- N. Branch Connections: Use lateral or conical branch connections.

3.2 INSTALLATION OF EXPOSED DUCTWORK

- A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

- B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.
- C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.
- D. Maintain consistency, symmetry, and uniformity in arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.
- E. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 DUCT SEALING

- A. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- B. Seal ducts at a minimum to the following seal classes in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":
 - 1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - 2. Outdoor, Supply-Air Ducts: Seal Class A.
 - 3. Outdoor, Exhaust Ducts: Seal Class C.
 - 4. Outdoor, Return-Air Ducts: Seal Class C.
 - 5. Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class B.
 - 6. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.
 - 7. Unconditioned Space, Exhaust Ducts: Seal Class C.
 - 8. Unconditioned Space, Return-Air Ducts: Seal Class B.
 - 9. Conditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class C.
 - 10. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class B.
 - 11. Conditioned Space, Exhaust Ducts: Seal Class B.
 - 12. Conditioned Space, Return-Air Ducts: Seal Class C.

3.4 HANGER AND SUPPORT INSTALLATION

- A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."
- B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
 - 1. Where practical, install concrete inserts before placing concrete.
 - 2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
 - 3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.
 - 4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.
- C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

- D. Hangers Exposed to View: Threaded rod and angle or channel supports.
- E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet.
- F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.5 CONNECTIONS

- A. Make connections to equipment with flexible connectors complying with Section 233300 "Air Duct Accessories."
- B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.6 PAINTING

- A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."

3.7 STARTUP

- A. Air Balance: Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

3.8 DUCT SCHEDULE

- A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:
 - 1. Fabricate all ducts to achieve SMACNA pressure class, seal class, and leakage class as indicated below.
 - 2. The first 20' of rectangular supply and return ductwork outside the HVAC room shall be constructed of 16 gauge sheet metal with a 6" wg static pressure classification for ductwork and transverse joints. The test pressure for duct leakage testing specified in 23 00 95, Testing, Adjusting and Balancing may be equal to that used for downstream ductwork.
- B. Supply Ducts:
 - 1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units :
 - a. Pressure Class: Positive 2- inch wg.
 - b. Minimum SMACNA Seal Class: C.
 - c. SMACNA Leakage Class for Rectangular: 16.
 - d. SMACNA Leakage Class for Round and Flat Oval: 8.
 - 2. Ducts Connected to Constant-Volume Air-Handling Units :
 - a. Pressure Class: Positive 2- 3- inch wg.
 - b. Minimum SMACNA Seal Class: B.

- c. SMACNA Leakage Class for Rectangular: 8.
 - d. SMACNA Leakage Class for Round and Flat Oval: 4.
 - 3. Ducts Connected to Variable-Air-Volume Air-Handling Units :
 - a. Pressure Class: Positive 4- inch wg.
 - b. Minimum SMACNA Seal Class: A B.
 - c. SMACNA Leakage Class for Rectangular: 4.
 - d. SMACNA Leakage Class for Round and Flat Oval: 2.
 - 4. Ducts Connected to Equipment Not Listed Above:
 - a. Pressure Class: Positive 3- inch wg.
 - b. Minimum SMACNA Seal Class: B.
 - c. SMACNA Leakage Class for Rectangular: 8.
 - d. SMACNA Leakage Class for Round and Flat Oval: 4.
- C. Return Ducts:
 - 1. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units :
 - a. Pressure Class: Positive or negative 2- inch wg.
 - b. Minimum SMACNA Seal Class: C.
 - c. SMACNA Leakage Class for Rectangular: 16.
 - d. SMACNA Leakage Class for Round and Flat Oval: 8.
 - 2. Ducts Connected to Air-Handling Units :
 - a. Pressure Class: Positive or negative 2- inch wg.
 - b. Minimum SMACNA Seal Class: A.
 - c. SMACNA Leakage Class for Rectangular: 16.
 - d. SMACNA Leakage Class for Round and Flat Oval: 8.
- D. Exhaust Ducts:
 - 1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:
 - a. Pressure Class: Negative 2- inch wg.
 - b. Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: 16.
 - d. SMACNA Leakage Class for Round and Flat Oval: 8.
 - 2. Ducts Connected to Air-Handling Units or Energy Recovery Units :
 - a. Pressure Class: Positive or negative 2- inch wg.
 - b. Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: 16.
 - d. SMACNA Leakage Class for Round and Flat Oval: 8.
 - 3. Ducts Connected to Equipment Not Listed above:
 - a. Pressure Class: Positive or negative 2- inch wg.
 - b. Minimum SMACNA Seal Class: A if negative pressure; A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: 16.
 - d. SMACNA Leakage Class for Round and Flat Oval.

E. Elbow Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."
 - a. Velocity 1000 fpm or Lower:
 - 1) Radius Type RE 1 with minimum 0.5 radius-to-diameter ratio.
 - 2) Mitered Type RE 4 without vanes.
 - b. Velocity 1000 to 1500 fpm:
 - 1) Radius Type RE 1 with minimum 1.0 radius-to-diameter ratio.
 - 2) Radius Type RE 3 with minimum 0.5 radius-to-diameter ratio and two vanes.
 - 3) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."
 - c. Velocity 1500 fpm or Higher:
 - 1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
 - 2) Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
 - 3) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."
2. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."
 - a. Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
 - b. Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
 - c. Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."
3. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."
 - a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.
 - 1) Velocity 1000 fpm or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.
 - 2) Velocity 1000 to 1500 fpm: 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.
 - 3) Velocity 1500 fpm or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.
 - 4) Radius-to Diameter Ratio: 1.5.
 - b. Round Elbows, 12 Inches and Smaller in Diameter: Stamped or pleated.
 - c. Round Elbows, 14 Inches and Larger in Diameter: Standing seam.

F. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."
 - a. Rectangular Main to Rectangular Branch: 45-degree entry.
 - b. Rectangular Main to Round Branch: Conical spin in.
2. Round and Flat Oval: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.
 - a. Velocity 1000 fpm or Lower: 90-degree tap.
 - b. Velocity 1000 to 1500 fpm: Conical tap.
 - c. Velocity 1500 fpm or Higher: 45-degree lateral.

END OF SECTION 233113

SECTION 233300 - AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

1. Backdraft and pressure relief dampers.
2. Barometric relief dampers.
3. Manual volume dampers.
4. Control dampers.
5. Fire dampers.
6. Smoke dampers.
7. Combination fire and smoke dampers.
8. Duct silencers.
9. Turning vanes.
10. Flexible connectors.

- B. Related Requirements:

1. Section 233346 "Flexible Ducts" for insulated and non-insulated flexible ducts.
2. Section 233723 "HVAC Gravity Ventilators" for roof-mounted ventilator caps.
3. Section 284621.11 "Addressable Fire-Alarm Systems" for duct-mounted fire and smoke detectors.
4. Section 284621.13 "Conventional Fire-Alarm Systems" for duct-mounted fire and smoke detectors.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.

1. For duct silencers, include pressure drop and dynamic insertion loss data.

- B. Shop Drawings: For duct accessories. Include plans, elevations, sections, details and attachments to other work.

1. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:
 - a. Special fittings.
 - b. Manual volume damper installations.
 - c. Control-damper installations.
 - d. Fire-damper, smoke-damper, combination fire- and smoke-damper, ceiling, and corridor damper installations, including sleeves; and duct-mounted access doors and remote damper operators.

- e. Duct security bars.
- f. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Source quality-control reports.

PART 2 - PRODUCTS

2.1 ASSEMBLY DESCRIPTION

- A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."
- B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

2.2 MATERIALS

- A. Galvanized Sheet Steel: Comply with ASTM A653/A653M.
 - 1. Galvanized Coating Designation: G90.
 - 2. Exposed-Surface Finish: Mill phosphatized.
- B. Stainless-Steel Sheets: Comply with ASTM A480/A480M, Type 304, and having a No. 2 finish for concealed ducts and finish for exposed ducts.
- C. Aluminum Sheets: Comply with ASTM B209, Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.
- D. Extruded Aluminum: Comply with ASTM B221, Alloy 6063, Temper T6.
- E. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.
- F. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.3 BACKDRAFT AND PRESSURE RELIEF DAMPERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Greenheck Fan Corporation.
 - 2. Nailor Industries Inc.
 - 3. Ruskin; Air Distribution Technologies, Inc.; Johnson Controls, Inc.
 - 4. United Enertech Corp.
- B. Description: Gravity balanced.

- C. Maximum Air Velocity: 1250 fpm.
- D. Maximum System Pressure: 2-inch wg.
- E. Frame: Hat-shaped, 0.05-inch- thick, galvanized sheet steel , with welded corners or mechanically attached.
- F. Blades: Multiple single-piece blades, end pivoted, maximum 6-inch width, 0.050-inch- thick aluminum sheet with sealed edges.
- G. Blade Action: Parallel.
- H. Blade Seals: Neoprene, mechanically locked.
- I. Blade Axles:
 - 1. Material: Stainless steel.
 - 2. Diameter: 0.20 inch.
- J. Tie Bars and Brackets: Galvanized steel.
- K. Return Spring: Adjustable tension.
- L. Bearings: Steel ball or synthetic pivot bushings.
- M. Accessories:
 - 1. Counterweights and spring-assist kits for vertical airflow installations.
 - 2. Screen Material: Galvanized steel.
 - 3. Screen Type: Bird.

2.4 BAROMETRIC RELIEF DAMPERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Greenheck Fan Corporation.
 - 2. Nailor Industries Inc.
 - 3. Ruskin; Air Distribution Technologies, Inc.; Johnson Controls, Inc.
 - 4. United Enertech Corp.
- B. Suitable for horizontal or vertical mounting.
- C. Maximum Air Velocity: 1250 fpm.
- D. Maximum System Pressure: 2-inch wg.
- E. Frame: Hat-shaped, 0.05-inch- thick, galvanized sheet steel , with welded corners or mechanically attached.
- F. Blades:
 - 1. Multiple, 0.050-inch- thick aluminum sheet.
 - 2. Maximum Width: 6 inches.
 - 3. Action: Parallel.
 - 4. Balance: Gravity.
 - 5. End pivoted.

- G. Blade Seals: Neoprene.
- H. Blade Axles: Stainless steel.
- I. Tie Bars and Brackets:
 - 1. Material: Galvanized steel.
 - 2. Rattle free with 90-degree stop.
- J. Return Spring: Adjustable tension.
- K. Bearings: Synthetic.
- L. Accessories:
 - 1. Flange on intake.
 - 2. Adjustment device to Permit Setting for varying differential static pressures.

2.5 MANUAL VOLUME DAMPERS

- A. Standard, Steel, Manual Volume Dampers:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Greenheck Fan Corporation.
 - b. Nailor Industries Inc.
 - c. Ruskin; Air Distribution Technologies, Inc.; Johnson Controls, Inc.
 - d. United Enertech Corp.
 - 2. Standard leakage rating.
 - 3. Suitable for horizontal or vertical applications.
 - 4. Frames:
 - a. Frame: Hat-shaped, 0.094-inch- thick, galvanized sheet steel.
 - b. Mitered and welded corners.
 - c. Flanges for attaching to walls and flangeless frames for installing in ducts.
 - 5. Blades:
 - a. Multiple or single blade.
 - b. Parallel- or opposed-blade design.
 - c. Stiffen damper blades for stability.
 - d. Galvanized -steel, 0.064 inch thick.
 - 6. Blade Axles: Galvanized steel.
 - 7. Bearings:
 - a. Molded synthetic.
 - b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
 - 8. Tie Bars and Brackets: Galvanized steel.

B. Jackshaft:

1. Size: 0.5-inch diameter.
2. Material: Galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.
3. Length and Number of Mountings: As required to connect linkage of each damper in multiple-damper assembly.

C. Damper Hardware:

1. Zinc-plated, die-cast core with dial and handle made of 3/32-inch- thick zinc-plated steel, and a 3/4-inch hexagon locking nut.
2. Include center hole to suit damper operating-rod size.
3. Include elevated platform for insulated duct mounting.

2.6 CONTROL DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Carnes Company.
2. Greenheck Fan Corporation.
3. Nailor Industries Inc.
4. Ruskin; Air Distribution Technologies, Inc.; Johnson Controls, Inc.
5. United Enertech Corp.

B. Low-leakage rating and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.

C. Frames:

1. Hat shaped.
2. 0.094-inch- thick, galvanized sheet steel.
3. Mitered and welded corners.

D. Blades:

1. Multiple blade with maximum blade width of 6 inches.
2. Opposed-blade design.
3. Galvanized-steel.
4. 0.064 inch thick single skin or 0.0747-inch- thick dual skin.
5. Blade Edging: Closed-cell neoprene.
6. Blade Edging: Inflatable seal blade edging, or replaceable rubber seals.

E. Blade Axles: 1/2-inch- diameter; stainless steel ; blade-linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.

1. Operating Temperature Range: From minus 40 to plus 200 deg F.

F. Bearings:

1. Molded synthetic.
2. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
3. Thrust bearings at each end of every blade.

2.7 FIRE DAMPERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Greenheck Fan Corporation.
 - 2. Ruskin; Air Distribution Technologies, Inc.; Johnson Controls, Inc.
 - 3. United Enertech Corp.
- B. Type: Static ; rated and labeled according to UL 555 by an NRTL.
- C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.
- D. Fire Rating: 1-1/2 hours.
- E. Frame: Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream; fabricated with roll-formed galvanized steel; with mitered and interlocking corners; gauge in accordance with UL listing.
- F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel; gauge in accordance with UL listing.
- G. Mounting Orientation: Vertical or horizontal as indicated.
- H. Blades: Roll-formed, interlocking, galvanized sheet steel; gauge in accordance with UL listing.
- I. Horizontal Dampers: Include blade lock and stainless-steel closure spring.
- J. Heat-Responsive Device: Replaceable, 165 deg F rated, fusible links.

2.8 SMOKE DAMPERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Greenheck Fan Corporation.
 - 2. Ruskin; Air Distribution Technologies, Inc.; Johnson Controls, Inc.
 - 3. United Enertech Corp.
- B. General Requirements: Label according to UL 555S by an NRTL.
- C. Smoke Detector: Integral, factory wired for single-point connection.
- D. Frame: Hat-shaped, galvanized sheet steel, with welded corners and mounting flange; gauge in accordance with UL listing.
- E. Blades: Roll-formed, horizontal, interlocking , galvanized sheet steel; gauge in accordance with UL listing.
- F. Leakage: Class II.
- G. Rated pressure and velocity to exceed design airflow conditions.
- H. Mounting Sleeve: Factory-installed, galvanized sheet steel; length to suit wall or floor application; gauge in accordance with UL listing.
- I. Damper Motors: two-position action.

- J. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
 3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
 4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
 5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F.
 6. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
 7. Electrical Connection: 115 V, single phase, 60 Hz.
- K. Accessories:
1. Auxiliary switches for signaling.
 2. Damper mounted.

2.9 COMBINATION FIRE AND SMOKE DAMPERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Greenheck Fan Corporation.
 2. Ruskin; Air Distribution Technologies, Inc.; Johnson Controls, Inc.
 3. United Enertech Corp.
- B. Type: Dynamic; rated and labeled according to UL 555 and UL 555S by an NRTL.
- C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.
- D. Fire Rating: 1-1/2 hours.
- E. Frame: Hat-shaped, galvanized sheet steel, with welded corners and mounting flange; gauge in accordance with UL listing.
- F. Heat-Responsive Device: , 165 deg F rated, fire-closure device.
- G. Heat-Responsive Device: Electric resettable device and switch package, factory installed, rated.
- H. Smoke Detector: Integral, factory wired for single-point connection.
- I. Blades: Roll-formed, horizontal, interlocking , galvanized sheet steel; gauge in accordance with UL listing.
- J. Leakage: Class I.
- K. Rated pressure and velocity to exceed design airflow conditions.

- L. Mounting Sleeve: Factory-installed, galvanized sheet steel; length to suit wall or floor application; gauge in accordance with UL listing.
- M. Master control panel for use in dynamic smoke-management systems.
- N. Damper Motors: two-position action.
- O. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - 1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 - 2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."
 - 3. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
 - 4. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
 - 5. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F.
 - 6. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
 - 7. Electrical Connection: 115 V, single phase, 60 Hz.
- P. Accessories:
 - 1. Auxiliary switches for signaling.
 - 2. Damper mounted.

2.10 DUCT SILENCERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Dynasonics.
 - 2. FläktGroup.
 - 3. IAC Acoustics; a division of Sound Seal.
 - 4. Price Industries.
 - 5. Vibro-Acoustics.
- B. General Requirements:
 - 1. Factory fabricated.
 - 2. Fire-Performance Characteristics: Adhesives, sealants, packing materials, and accessory materials shall have flame-spread index not exceeding 25 and smoke-developed index not exceeding 50 when tested according to ASTM E84.
 - 3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- C. Shape:
 - 1. Rectangular straight with splitters or baffles.

- D. Rectangular Silencer Outer Casing: ASTM A653/A653M, G90 , galvanized sheet steel, 0.034 inch thick.
- E. Round Silencer Outer Casing: ASTM A653/A653M, G90 , galvanized sheet steel.
 - 1. Sheet Metal Thickness for Units up to 24 Inches in Diameter: 0.034 inch thick.
 - 2. Sheet Metal Thickness for Units 26 through 40 Inches in Diameter: 0.040 inch thick.
 - 3. Sheet Metal Thickness for Units 42 through 52 Inches in Diameter: 0.05 inch thick.
 - 4. Sheet Metal Thickness for Units 54 through 60 Inches in Diameter: 0.064 inch thick.
- F. Inner Casing and Baffles: ASTM A653/A653M, G90 galvanized sheet metal, 0.034 inch thick, and with 1/8-inch- diameter perforations.
- G. Connection Sizes: Match connecting ductwork unless otherwise indicated.
- H. Principal Sound-Absorbing Mechanism:
 - 1. Controlled impedance membranes and broadly tuned resonators without absorptive media.
 - 2. Film-lined type with fill material.
 - a. Fill Material: Inert and vermin-proof fibrous material, packed under not less than 5 percent compression.
 - 3. Lining: See Schedule.
- I. Fabricate silencers to form rigid units that will not pulsate, vibrate, rattle, or otherwise react to system pressure variations. Do not use mechanical fasteners for unit assemblies.
 - 1. Joints: Lock formed and sealed.
 - 2. Suspended Units: Factory-installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
 - 3. Reinforcement: Cross or trapeze angles for rigid suspension.
- J. Accessories:
 - 1. Factory-installed end caps to prevent contamination during shipping.
 - 2. Removable splitters.
 - 3. Airflow measuring devices.
- K. Source Quality Control: Test according to ASTM E477.
 - 1. Record acoustic ratings, including dynamic insertion loss and generated-noise power levels with an airflow of at least 1000-fpm face velocity.
 - 2. Leak Test: Test units for airtightness at 200 percent of associated fan static pressure or 6-inch wg static pressure, whichever is greater.

2.11 TURNING VANES

- A. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.
 - 1. Acoustic Turning Vanes: Fabricate airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.

- B. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 4-3, "Vanes and Vane Runners," and 4-4, "Vane Support in Elbows."
- C. Vane Construction: Single wall.
- D. Vane Construction: Single wall for ducts up to 48 inches wide and double wall for larger dimensions.

2.12 FLEXIBLE CONNECTORS AND THRUST RESTRAINTS

- A. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.
- B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.
- C. Install backdraft control dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.
- D. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.
 - 1. Install steel volume dampers in steel ducts.
 - 2. Install aluminum volume dampers in aluminum ducts.
- E. Set dampers to fully open position before testing, adjusting, and balancing.
- F. Install test holes at fan inlets and outlets and elsewhere as indicated.
- G. Install fire and smoke dampers according to UL listing.
- H. Connect ducts to duct silencers rigidly.
- I. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:
 - 1. On both sides of duct coils.
 - 2. Upstream and downstream from duct filters.
 - 3. At outdoor-air intakes and mixed-air plenums.
 - 4. At drain pans and seals.

5. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
 6. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
 7. At each change in direction and at maximum 50-foot spacing.
 8. Upstream and downstream from turning vanes.
 9. Upstream or downstream from duct silencers.
 10. Control devices requiring inspection.
 11. Elsewhere as indicated.
- J. Install flexible connectors and thrust restraints to connect ducts to equipment as required by Section 230548 "Vibration and Seismic Control for HVAC" or 230548.13 "Vibration Control for HVAC" and as shown in Drawing General Notes, Plans, and/or Details.
- K. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.
- L. Install duct test holes where required for testing and balancing purposes.

END OF SECTION 233300

SECTION 233346 - FLEXIBLE DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Insulated flexible ducts.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1 ASSEMBLY DESCRIPTION

- A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."
- B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
- C. Comply with the Air Diffusion Council's "ADC Flexible Air Duct Test Code FD 72-R1."
- D. Comply with ASTM E 96/E 96M, "Test Methods for Water Vapor Transmission of Materials."

2.2 INSULATED FLEXIBLE DUCTS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Flexmaster U.S.A., Inc.
 - 2. Thermaflex; a Flex-Tek Group company.
- B. Insulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene vapor-barrier film.
 - 1. Pressure Rating: 4-inch wg positive and 0.5-inch wg negative.
 - 2. Maximum Air Velocity: 4000 fpm.
 - 3. Temperature Range: Minus 20 to plus 175 deg F.

4. Insulation R-Value: R6.

2.3 FLEXIBLE DUCT CONNECTORS

- A. Clamps: Nylon strap in sizes 3 through 18 inches, to suit duct size.
- B. Non-Clamp Connectors.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install flexible ducts according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.
- B. Install in indoor applications only. Flexible ductwork should not be exposed to UV lighting.
- C. Connect terminal units to supply ducts directly or with maximum 12-inch lengths of flexible duct. Do not use flexible ducts to change directions.
- D. Connect diffusers or light troffer boots to ducts directly or with maximum 60-inch lengths of flexible duct clamped or strapped in place.
- E. Connect flexible ducts to metal ducts with draw bands.
- F. Install duct test holes where required for testing and balancing purposes.
- G. Installation:
 1. Install ducts fully extended.
 2. Do not bend ducts across sharp corners.
 3. Bends of flexible ducting shall not exceed a minimum of one duct diameter.
 4. Avoid contact with metal fixtures, water lines, pipes, or conduits.
 5. Install flexible ducts in a direct line, without sags, twists, or turns.
- H. Supporting Flexible Ducts:
 1. Suspend flexible ducts with bands 1-1/2 inches wide or wider and spaced a maximum of 48 inches apart. Maximum centerline sag between supports shall not exceed 1/2 inch per 12 inches.
 2. Install extra supports at bends placed approximately one duct diameter from center line of the bend.
 3. Ducts may rest on ceiling joists or truss supports. Spacing between supports shall not exceed the maximum spacing per manufacturer's written installation instructions.
 4. Vertically installed ducts shall be stabilized by support straps at a maximum of 72 inches o.c.

END OF SECTION 233346

SECTION 233413 - AXIAL HVAC FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:

- 1. Tubeaxial fans.

1.1 ACTION SUBMITTALS

- B. Product Data: For each type of product.

- 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes for fans.
 - 2. Include rated capacities, furnished specialties, and accessories for each fan.
 - 3. Fans:
 - a. Certified fan performance curves with system operating conditions indicated.
 - b. Certified fan sound-power ratings.
 - c. Fan construction and accessories.
 - d. Motor ratings and electrical characteristics, plus motor and electrical accessories.
 - e. Fan speed controllers.
 - 4. Dampers, including housings, linkages, and operators.

1.3 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For fans, include the following:

- 1. Operation in normal and emergency modes.
 - 2. Operation and maintenance manuals.

1.4 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective coverage for storage and identified with labels describing contents.
 - 1. Belts: One set(s) for each belt-driven unit.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.

2.2 TUBEAXIAL FANS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Acme Engineering & Manufacturing Corp.
 2. Aerovent; a division of Twin City Fan Companies, Ltd.
 3. Chicago Blower Corporation.
 4. Cincinnati Fan.
 5. Greenheck Fan Corporation.
 6. New York Blower Company (The).
- B. Source Limitations: Obtain tubeaxial fans from single manufacturer.
- C. Description: Fan wheel and housing, factory-mounted motor with direct drive, an inlet cone section, and accessories.
- D. Housings: Aluminum with flanged inlet and outlet connections.
- E. Wheel Assemblies: Cast or extruded aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key.
- F. Belt Drives:
1. Factory mounted, with adjustable alignment and belt tensioning.
 2. Service Factor Based on Fan Motor Size: 1.2.
 3. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
 4. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
 5. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
 6. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
 7. Belt Guards: Fabricate of prime-coated steel to comply with OSHA and SMACNA requirements for motors with exposed drive belt. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
 8. Motor Base: Adjustable rail mount motor base with adjustment screw to set belt tension.
 9. Shaft Bearings: Radial, self-aligning bearings.
 - a. Ball-Bearing Rating Life: ABMA 9, L10 of 50,000 hours.
 - b. Extend lubrication lines to outside of casing and terminate with grease fittings.
- G. Accessories:
1. Companion Flanges: Rolled flanges of same material as housing.
 2. Inspection Door: Bolted door allowing limited access to internal parts of fan, of same material as housing.

3. Swingout Construction: Assembly allowing entire fan section to swing out from duct for cleaning and servicing, of same material as housing.
4. Mounting Clips: clips welded to fan housing, of same material as housing.
5. Shaft Seal: Elastomeric seal and PTFE wear plate, suitable for up to 300 deg F.
6. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
7. Inlet Cone: Round-to-round transition, of same material as housing.
8. Outlet Cone: Round-to-round transition, of same material as housing.
9. Direct-Driven Units: Encase motor in housing outside of airstream. Extend lubrication lines to outside of casing and terminate with grease fittings.

H. Factory Finishes:

1. Sheet Metal Parts: Prime coat before final assembly.
2. Exterior Surfaces: Baked-enamel finish coat after assembly.

PART 3 - EXECUTION

3.1 INSTALLATION, GENERAL

- A. Install axial fans level and plumb.
- B. Disassemble and reassemble units, as required for moving to the final location, in accordance with manufacturer's written instructions.
- C. Lift and support units with manufacturer's designated lifting or supporting points.
- D. Equipment Mounting:
 1. Support duct-mounted and other hanging axial fans directly from the building structure, using suitable hanging systems as specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
 2. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- E. Install units with adequate clearances for service and maintenance.
- F. Label fans in accordance with requirements specified in Section 230553 "Identification for HVAC Piping and Equipment."

3.2 DUCTWORK CONNECTIONS

- A. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Section 233300 "Air Duct Accessories."
- B. Where installing ducts adjacent to fans, allow space for service and maintenance.

3.3 ELECTRICAL CONNECTIONS

- A. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

- B. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."
- C. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.
- D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.
 - 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
 - 2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.4 CONTROL CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.
- B. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

3.5 STARTUP SERVICE:

- A. Perform startup service.
 - 1. Complete installation and startup checks in accordance with manufacturer's written instructions.
 - 2. Verify that shipping, blocking, and bracing are removed.
 - 3. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
 - 4. Verify that cleaning and adjusting are complete.
 - 5. For direct-drive fans, verify proper motor rotation direction and verify fan wheel free rotation and smooth bearing operation.
 - 6. For belt-drive fans, disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
 - 7. Adjust belt tension.
 - 8. Adjust damper linkages for proper damper operation.
 - 9. Verify lubrication for bearings and other moving parts.
 - 10. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
 - 11. Disable automatic temperature-control operators, energize motor and confirm proper motor rotation and unit operation, adjust fan to indicated rpm, and measure and record motor voltage and amperage.
 - 12. Shut unit down and reconnect automatic temperature-control operators.
 - 13. Remove and replace malfunctioning units and retest as specified above.

3.6 ADJUSTING

- A. Adjust damper linkages for proper damper operation.
- B. Adjust belt tension.
- C. Lubricate bearings.

- D. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

3.7 CLEANING

- A. After completing system installation and testing, adjusting, and balancing and after completing startup service, clean fans internally to remove foreign material and construction dirt and dust.

3.8 DEMONSTRATION

- A. Train Owner's maintenance personnel to adjust, operate, and maintain axial HVAC fans.

END OF SECTION 233413

SECTION 233416 - CENTRIFUGAL HVAC FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.1 SUMMARY

- B. Section Includes:
 - 1. Backward-inclined centrifugal fans, including airfoil and curved blade fans.
 - 2. Square in-line centrifugal fans.
 - 3. Utility set fans.

1.2 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes for fans.
 - 2. Rated capacities, operating characteristics, and furnished specialties and accessories.
 - 3. Certified fan performance curves with system operating conditions indicated.
 - 4. Certified fan sound-power ratings.
 - 5. Motor ratings and electrical characteristics, plus motor and electrical accessories.
 - 6. Material thickness and finishes, including color charts.
 - 7. Dampers, including housings, linkages, and operators.

1.3 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For centrifugal fans to include in normal operation, emergency operation, and maintenance manuals with replacement parts listing.

PART 2 - PRODUCTS

2.1 BACKWARD-INCLINED CENTRIFUGAL FANS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Greenheck Fan Corporation.
 - 2. Loren Cook Company.
 - 3. Twin City Fan & Blower.

B. Description:

1. Factory-fabricated, -assembled, -tested, and -finished, direct-driven centrifugal fans, consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, and support structure. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations.
2. Factory-installed and -wired disconnect switch.

C. Housings:

1. Housing Material: Reinforced steel.
2. Housing Coating: None.
3. Housing Assembly: Sideplates continuously welded or spot welded or attached by continuous Pittsburgh lock seal or similar seal.
4. Formed panels to make curved-scroll housings with shaped cutoff.
5. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
6. Spun inlet cone with flange.
7. Outlet flange.
8. Discharge Arrangement: Fan scroll housing is field rotatable to any of seven discharge positions. Provide fan with discharge positioned in proper direction to minimize connected duct turns.

D. Wheels:

1. Wheel Configuration: SWSI construction with a precision-spun curved inlet flange and a backplate fastened to shaft with setscrews. Wheels shall be statically and dynamically balanced, and nonoverloading.
2. Wheel and Blade Material: Steel.
 - a. Spark-Resistant Construction: Classified according to AMCA 99, Type C.
3. Wheel and Blade Coating: None.
4. Cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.
5. Backward-Inclined Airfoil Blades:
 - a. Aerodynamic design.
 - b. Heavy backplate.
 - c. Hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate.

E. Shafts:

1. Statically and dynamically balanced, and selected for continuous operation at maximum rated fan speed and motor horsepower, with adjustable alignment and belt tensioning.
2. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
3. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

F. Bearings:

1. Grease-Lubricated Shaft Bearings, Ball or Roller:
 - a. Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.
 - b. Ball-Bearing Rating Life: ABMA 9, L(10) at 50,000 hours.
 - c. Roller-Bearing Rating Life: ABMA 11, L(10) at 50,000 hours.
 - d. Extended Lubrication Lines: Extend lines to accessible location.

G. Motor Enclosure: Open, dripproof.

H. Accessories:

1. Access for Inspection, Cleaning, and Maintenance: Comply with requirements in ASHRAE 62.1.
2. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
3. Companion Flanges: Rolled flanges for duct connections of same material as housing.
4. Inlet Screens: Grid screen of same material as housing.
5. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.

2.2 SQUARE IN-LINE CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, undefined:

1. Greenheck Fan Corporation.
2. Loren Cook Company.
3. Twin City Fan & Blower.

B. Description: Square in-line centrifugal fans.

C. Housing:

1. Housing Material: Reinforced steel.
2. Housing Coating: Phenolic.
3. Housing Construction: Side panels shall be easily removable for service. Include inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.

D. Direct-Drive Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing.

E. Fan Wheels: Aluminum airfoil blades welded to aluminum hub.

F. Motor Enclosure: Open, dripproof.

G. Accessories:

1. Access for Inspection, Cleaning, and Maintenance: Comply with requirements in ASHRAE 62.1.

2.3 UTILITY SET FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Greenheck Fan Corporation.
2. Loren Cook Company.
3. Twin City Fan & Blower.

B. Description:

1. Factory-fabricated, -assembled, -tested, and -finished, direct-driven centrifugal fan utility vent sets, consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, and support structure.

C. Housings:

1. Housing Material: Reinforced steel.
2. Housing Coating: Phenolic.
3. Formed panels to make curved-scroll housings with shaped cutoff.
4. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
5. Discharge Arrangement: Fan scroll housing field rotatable to any of seven discharge positions. Provide fan with discharge positioned in proper direction to minimize connected duct turns.

D. Wheels:

1. Wheel Configuration: SWSI, with hub keyed to shaft.
2. Wheel and Blade Materials: Steel.
 - a. Spark-Resistant Construction: Classified according to AMCA 99, Type B.
3. Wheel and Blade Coating: Phenolic.
4. Backward-Inclined Airfoil Blades:
 - a. Aerodynamic design.
 - b. Heavy backplate.
 - c. Hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate.

E. Shafts:

1. Turned, ground, and polished steel; keyed to wheel hub. First critical speed at least 1.4 times maximum class speed.

F. Bearings:

1. Heavy-duty regreasable ball or roller type in a cast iron pillowblock housing.
2. Ball-Bearing Rating Life: ABMA 9, L(50) of 200,000 hours.
3. Roller-Bearing Rating Life: ABMA 11, L(50) of 200,000 hours.
4. Extend grease fitting to accessible location outside of unit.

G. Motor Enclosure: Explosion-proof.

H. Accessories:

1. Inlet and Outlet: Flanged.
2. Backdraft Dampers: Gravity actuated with counterweight and interlocking aluminum blades, with felt edges in steel frame installed on fan discharge.
3. Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.

2.4 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
- B. Where variable-frequency drives are indicated or scheduled, provide fan motor compatible with variable-frequency drive.

PART 3 - EXECUTION

3.1 INSTALLATION OF CENTRIFUGAL HVAC FANS

- A. Install centrifugal fans level and plumb.
- B. Disassemble and reassemble units, as required for moving to the final location, according to manufacturer's written instructions.
- C. Lift and support units with manufacturer's designated lifting or supporting points.
- D. Equipment Mounting:
 - 1. Support duct-mounted and other hanging centrifugal fans directly from the building structure, using suitable hanging systems as specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
 - 2. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- E. Curb Support, Field Built-Up: Install roof curb on roof structure, level and secure, according to "The NRCA Roofing and Waterproofing Manual," detail "Equipment Support Curb," number "SPF-9" (page 1409) and detail "Equipment Support Curb," number "SPF-9S" (page 1410). Install and secure centrifugal fans on curbs, and coordinate roof penetrations and flashing with roof construction.
- F. Curb Support, Prefabricated: Rail-type wood support provided by fan manufacturer.
- G. Unit Support: Install centrifugal fans level on structural curbs. Coordinate wall penetrations and flashing with wall construction. Secure units to structural support with anchor bolts.
- H. Install units with clearances for service and maintenance.
- I. Label fans according to requirements specified in Section 230553 "Identification for HVAC Piping and Equipment."

3.2 DUCTWORK AND PIPING CONNECTIONS

- A. Drawings indicate general arrangement of ducts and duct accessories.
- B. Install ducts adjacent to fans to allow service and maintenance.
- C. Install piping from scroll drain connection, with trap with seal equal to 1.5 times specified static pressure, to nearest floor drain with pipe sizes matching the drain connection.
- D. Install heat tracing on all drain piping subject to freezing temperature and as indicated on Drawings. Furnish and install heat tracing according to Section 230533 "Heat Tracing for HVAC Piping."

3.3 ELECTRICAL CONNECTIONS

- A. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

- C. Install electrical devices furnished by manufacturer, but not factory mounted, according to NFPA 70 and NECA 1.
 - 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
 - 2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.4 CONTROL CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.
- B. Connect control wiring according to Section 260523 "Control-Voltage Electrical Power Cables."

3.5 ADJUSTING

- A. Adjust damper linkages for proper damper operation.
- B. Adjust belt tension.
- C. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.
- D. Replace fan and motor pulleys as required to achieve design airflow.
- E. Lubricate bearings.

END OF SECTION 233416

SECTION 233433.13 - COMMERCIAL AIR CURTAINS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes commercial air-curtain unit.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, and furnished specialties and accessories.
- B. Shop Drawings: For air curtain units.
 - 1. Include plans, elevations, sections, and attachment details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.
- C. Delegated Design Submittal: For air curtain units indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by a qualified professional engineer responsible for their preparation.
 - 1. Detail fabrication and assembly of air-curtain unit mounting assemblies.
 - 2. Include design calculations for selecting vibration isolators.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air curtain units to include in operation and maintenance manuals.

1.5 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of air curtain units that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period (Nonheating Units): 60 months.

PART 2 - PRODUCTS

2.1 COMMERCIAL AIR-CURTAIN UNIT

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Berner International.
 - 2. Fantech.
 - 3. Loren Cook Company.
 - 4. Marley Engineered Products.
 - 5. Mars Air Doors; Mars Air Systems.
- B. Source Limitations: Obtain air curtain from single source from single manufacturer.
- C. Housing:
 - 1. Galvanized Steel: Galvanized steel with electrostatically applied, epoxy-enamel, powder-coat finish.
 - 2. Discharge: Integral to housing, connection for ductwork.
- D. Mounting Brackets: Galvanized steel, for above ceiling installation application.
- E. Air-Intake Grilles:
 - 1. Grilles: Integral to, and same material as, housing.
- F. Fans:
 - 1. Centrifugal, forward curved, double width, double inlet.
 - 2. Painted steel.
 - 3. Statically and dynamically balanced.
 - 4. Direct drive.
- G. Motors: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - 1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 - 2. Single speed.
 - 3. Resiliently mounted.
 - 4. Continuous duty.
 - 5. Totally enclosed, air over.
 - 6. Integral thermal-overload protection.
 - 7. Bearings: Permanently sealed, lifetime, prelubricated, ball bearings.
 - 8. Disconnect: Lockable disconnect.
- H. Controls:
 - 1. Automatic Door Switch: Magnetic, installed in door area to activate air curtain when door opens and to deactivate air curtain when door closes.
 - 2. Motor-Control Panel: Complete with motor starter, 115-V ac transformer with primary and secondary fuses, terminal strip, and NEMA 250, Type 1 enclosure with door-mounted, HAND-OFF-AUTO switch.

I. Accessories:

1. Mounting Brackets: Adjustable mounting brackets for wall mounting.
2. Discharge Extension Neck: For ceiling-recessed installation.

2.2 SOURCE QUALITY CONTROL

- A. Source Quality Control: Test to 300 and 200 psig underwater.
- B. Testing: Test and inspect steam coils in accordance with ASHRAE 33.
- C. AMCA Certification for Fan Aerodynamic Performance Rating: Test, rate, and label, air curtain units in accordance with AMCA 211.
- D. AMCA Certification for Fan Sound Performance Rating: Test, rate, and label, air curtain units in accordance with AMCA 311.
- E. Comply with AHRI 410, "Forced-Circulation Air-Cooling and Air-Heating Coils," for components, construction, and rating.
- F. Comply with NSF 37, "Air Curtains for Entranceways in Food and Food Service Establishments."
- G. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and use.
- H. Steam coil will be considered defective if it does not pass tests and inspections.
- I. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine work areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Install air curtains with clearance for equipment service and maintenance.
- B. Equipment Installation: Install air curtains. Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- C. Comply with requirements for hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

3.3 PIPING CONNECTIONS

- A. Comply with requirements for heating hot-water piping specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Comply with requirements for steam piping specified in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Heating Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- C. Where installing piping adjacent to equipment, allow space for service and maintenance.

3.4 ELECTRICAL CONNECTIONS

- A. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."
- C. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.
- D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.
 - 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
 - 2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.5 CONTROL CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.
- B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

3.6 ADJUSTING

- A. Adjust motor speed to achieve specified airflow.
- B. Adjust discharge louver and dampers to regulate airflow.
- C. Adjust air-directional vanes.

3.7 FIELD QUALITY CONTROL

- A. Testing Agency: will engage a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.

C. Tests and Inspections:

1. After installing air curtains completely, perform visual and mechanical check of individual components.
2. After electrical circuitry has been energized, start unit to confirm motor rotation and unit operation. Certify compliance with test parameters.
3. Inspect for leaks.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Air-curtain unit will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

END OF SECTION 233433.13

SECTION 233600 - AIR TERMINAL UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Modulating, single-duct air terminal units.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of air terminal unit.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for air terminal units.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Ceiling suspension assembly members.
 - 2. Size and location of initial access modules for acoustic tile.
 - 3. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."
- C. ASHRAE Compliance: Applicable requirements in ASHRAE/IES 90.1, "Section 6 - Heating, Ventilating, and Air Conditioning."

2.2 MODULATING, SINGLE-DUCT AIR TERMINAL UNITS

- A. Manufacturers: Subject to compliance with requirements, undefined:
 - 1. ENVIRO-TEC; by Johnson Controls, Inc.
 - 2. Krueger.
 - 3. METALAIRE, Inc.
 - 4. Nailor Industries Inc.
 - 5. Price Industries.
 - 6. Titus.
- B. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.
- C. Casing: 0.034-inch- thick galvanized steel, double wall.
 - 1. Casing Liner: Comply with requirements in "Casing Liner" Article for fibrous-glass duct liner.
 - 2. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
 - 3. Air Outlet: S-slip and drive connections.
 - 4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket, upstream of reheat coil.
 - 5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
 - 1. Maximum Damper Leakage: AHRI 880 rated, 3 percent of nominal airflow at 3-inch wg inlet static pressure.
 - 2. Damper Position: Normally open.
- E. Attenuator Section: 0.032-inch aluminum sheet.
 - 1. Attenuator Section Liner: Comply with requirements in "Casing Liner" Article for fibrous-glass duct liner.
 - 2. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- F. Hydronic Heating Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve. Coil shall be integral to terminal unit casing. Provide hydronic heating coils for air terminal units scheduled on Drawings.
- G. Control Sequences:
 - 1. Occupied:
 - a. On a call for cooling, airflow will increase as the damper opens towards maximum setting to satisfy set point.
 - b. On a call for less cooling, airflow will decrease as the damper closes towards minimum setting to satisfy set point.
 - c. On a call for heating, after terminal unit has reached minimum airflow set point, hydronic heating coil valve will modulate toward open to satisfy set point.

2. Unoccupied:
 - a. Damper closes to minimum setting.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT INSTALLATION

- A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 5, "Hangers and Supports" and with Section 230529 "Hangers and Supports for HVAC Piping and Equipment."
- B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
 1. Where practical, install concrete inserts before placing concrete.
 2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
 3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes and for slabs more than 4 inches thick.
 4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes and for slabs less than 4 inches thick.
 5. Do not use powder-actuated concrete fasteners for seismic restraints.
- C. Hangers Exposed to View: Threaded rod and angle or channel supports.
- D. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.2 SEISMIC-RESTRAINT-DEVICE INSTALLATION

- A. Install hangers and braces designed to support the air terminal units and to restrain against seismic forces required by applicable building codes. Comply with ASCE/SEI 7. Comply with requirements for seismic-restraint devices in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.
- C. Install cables so they do not bend across edges of adjacent equipment or building structure.
- D. Install cable restraints on air terminal units that are suspended with vibration isolators.
- E. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction.
- F. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure, to flanges of beams, to upper truss chords of bar joists, or to concrete members.
- G. Drilling for and Setting Anchors:
 1. Identify position of reinforcing steel and other embedded items before drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.

2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Wedge Anchors: Protect threads from damage during anchor installation. Install heavy-duty sleeve anchors with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Set anchors to manufacturer's recommended torque, using a torque wrench.
5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

3.3 TERMINAL UNIT INSTALLATION

- A. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."
- B. Install air terminal units level and plumb. Maintain sufficient clearance for normal service and maintenance.
- C. Install wall-mounted thermostats.
- D. Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- E. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

3.4 PIPING CONNECTIONS

- A. Where installing piping adjacent to air terminal unit, allow space for service and maintenance.
- B. Hot-Water Piping: Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties," and connect heating coils to supply with shutoff valve, strainer, control valve, and union or flange; and to return with balancing valve and union or flange.

3.5 DUCTWORK CONNECTIONS

- A. Comply with requirements in Section 233113 "Metal Ducts" for connecting ducts to air terminal units.

3.6 ELECTRICAL CONNECTIONS

- A. Install field power to each air terminal unit electrical power connection. Coordinate with air terminal unit manufacturer and installers.
- B. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."
- D. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.

- E. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.
 - 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
 - 2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.7 CONTROL CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.
- B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

3.8 IDENTIFICATION

- A. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Section 230553 "Identification for HVAC Piping and Equipment" for equipment labels and warning signs and labels.

END OF SECTION 233600

SECTION 233713.13 - AIR DIFFUSERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Rectangular and square ceiling diffusers.
 - 2. Perforated diffusers.
 - 3. Linear slot diffusers.
- B. Related Requirements:
 - 1. Section 233300 "Air Duct Accessories" for fire and smoke dampers and volume-control dampers not integral to diffusers.
 - 2. Section 233713.23 "Air Registers and Grilles" for adjustable-bar register and grilles, fixed-face registers and grilles, and linear bar grilles.
 - 3. Section 233713.43 "Security Registers and Grilles" for security registers and security grilles.
 - 4. Section 233716 "Fabric Air-Diffusion Devices" for continuous tubular diffusers.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
 - 2. Diffuser Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

PART 2 - PRODUCTS

2.1 RECTANGULAR AND SQUARE CEILING DIFFUSERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Nailor Industries Inc.
 - 2. Price Industries.
 - 3. Titus, a division of Air System Components; Johnson Controls, Inc.
- B. Devices shall be specifically designed for variable-air-volume flows.
- C. Material: Steel.

- D. Finish: Baked enamel, color selected by Architect.
- E. Face Size: 24 by 24 inches.
- F. Face Style: Plaque.
- G. Pattern: Adjustable.
- H. Dampers: Butterfly.
- I. Accessories:
 - 1. Equalizing grid.
 - 2. Plaster ring.
 - 3. Safety chain.
 - 4. Wire guard.
 - 5. Sectorizing baffles.
 - 6. Operating rod extension.

2.2 PERFORATED DIFFUSERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Nailor Industries Inc.
 - 2. Price Industries Limited.
 - 3. Titus; brand of Johnson Controls International plc, Global Products.
- B. Devices shall be specifically designed for variable-air-volume flows.
- C. Material: Steel backpan and pattern controllers, with steel face.
- D. Finish: Baked enamel, color selected by Architect.
- E. Face Size: 24 by 24 inches.
- F. Duct Inlet: Round.
- G. Face Style: Flush.
- H. Pattern Controller: Adjustable with louvered pattern modules at inlet.
- I. Dampers: Butterfly.
- J. Accessories:
 - 1. Equalizing grid.
 - 2. Plaster ring.
 - 3. Safety chain.
 - 4. Wire guard.
 - 5. Sectorizing baffles.
 - 6. Operating rod extension.

2.3 LINEAR SLOT DIFFUSERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Nailor Industries Inc.
 - 2. Price Industries Limited.
 - 3. Titus; brand of Johnson Controls International plc, Global Products.
- B. Devices shall be specifically designed for variable-air-volume flows.
- C. Material - Shell: Steel , insulated.
- D. Material - Pattern Controller and Tees: Aluminum.
- E. Finish - Face and Shell: Baked enamel, black.
- F. Finish - Pattern Controller: Baked enamel, black.
- G. Finish - Tees: Baked enamel, white.
- H. Provide plenums full length of diffuser. See drawings for sizes.

2.4 SOURCE QUALITY CONTROL

- A. Verification of Performance: Rate diffusers according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas where diffusers are installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install diffusers level and plumb.
- B. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.
- C. Install diffusers with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3 ADJUSTING

- A. After installation, adjust diffusers to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 233713.13

SECTION 233713.23 - REGISTERS AND GRILLES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Adjustable blade face registers and grilles.
 - 2. Fixed face registers and grilles.
- B. Related Requirements:
 - 1. Section 233300 "Air Duct Accessories" for fire and smoke dampers and volume-control dampers not integral to registers and grilles.
 - 2. Section 233713.13 "Air Diffusers" for various types of air diffusers.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
 - 2. Register and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

PART 2 - PRODUCTS

2.1 REGISTERS

- A. Adjustable Blade Face Register (supply air type):
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Nailor Industries Inc.
 - b. Price Industries Limited.
 - c. Titus; brand of Johnson Controls International plc, Global Products.
 - 2. Material: Steel.
 - 3. Finish: Baked enamel, white.
 - 4. Face Blade Arrangement: Horizontal spaced 3/4 inch apart.
 - 5. Core Construction: Integral.
 - 6. Rear-Blade Arrangement: Vertical spaced 3/4 inch apart.

7. Frame: 1 inch wide.
8. Mounting: Countersunk screw.
9. Damper Type: Adjustable opposed blade.
10. Accessories:
 - a. Rear-blade gang operator.
 - b. Filter.

B. Fixed Face Register (return or exhaust air type):

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Nailor Industries Inc.
 - b. Price Industries Limited.
 - c. Titus; brand of Johnson Controls International plc, Global Products.
2. Material: Steel.
3. Finish: Baked enamel, white.
4. Face Blade Arrangement: spaced 3/4 inch apart.
5. Face Arrangement: Perforated core.
6. Core Construction: Integral.
7. Frame: 1 inch wide.
8. Mounting: Countersunk screw.
9. Damper Type: Adjustable opposed blade.
10. Accessory: Filter.

2.2 GRILLES

A. Adjustable Blade Face Grille (supply air type):

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Nailor Industries Inc.
 - b. Price Industries Limited.
 - c. Titus; brand of Johnson Controls International plc, Global Products.
2. Material: Steel.
3. Finish: Baked enamel, white.
4. Face Blade Arrangement: Horizontal spaced 3/4 inch apart.
5. Core Construction: Integral.
6. Rear-Blade Arrangement: Vertical spaced 3/4 inch apart.
7. Frame: 1 inch wide.
8. Mounting: Countersunk screw.

B. Fixed Face Grille (return or exhaust air type) :

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Nailor Industries Inc.
 - b. Price Industries Limited.
 - c. Titus; brand of Johnson Controls International plc, Global Products.
2. Material: Steel.
3. Finish: Baked enamel, white.

4. Face Blade Arrangement: ; spaced 3/4 inch apart.
5. Face Arrangement: Perforated core.
6. Core Construction: Integral.
7. Frame: 1 inch wide.
8. Mounting: Countersunk screw.
9. Accessory: Filter.

2.3 SOURCE QUALITY CONTROL

- A. Verification of Performance: Rate registers and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas where registers and grilles are installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install registers and grilles level and plumb.
- B. Outlets and Inlets Locations: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.
- C. Install registers and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3 ADJUSTING

- A. After installation, adjust registers and grilles to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 233713.23

SECTION 235216 - CONDENSING BOILERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes gas-fired, fire-tube floor-mounted condensing boilers, trim, and accessories for generating hot water.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for boilers.
 - 2. Include rated capacities, operating characteristics, and furnished specialties and accessories.
- B. Sustainable Design Submittals:
 - 1. Product data showing compliance with ASHRAE 90.1.
- C. Shop Drawings: For boilers, boiler trim, and accessories.
 - 1. Include plans, elevations, sections, and mounting details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans and sections, drawn to scale and coordinated with each other, using input from installers of the items involved.
- B. Product Certificates:
 - 1. ASME Stamp Certification and Report: Submit "A," "S," or "PP" stamp certificate of authorization, as required by authorities having jurisdiction, and document hydrostatic testing of piping external to boiler.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For boilers to include in emergency, operation, and maintenance manuals.

1.6 WARRANTY

- A. Manufacturer's Warranty: Manufacturer agrees to repair or replace components of boilers that fail in materials or workmanship within specified warranty period. Where "prorated" is indicated, the boiler manufacturer will cover the indicated percentage of cost of replacement parts. With "prorated" type, covered cost decreases as age of equipment increases.
 - 1. Warranty Period for Floor-Mounted Fire-Tube Condensing Boilers:
 - a. Heat Exchanger and Tank: Free from defects in material and workmanship.
 - b. Warranty Coverage: for 10 years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASME Compliance: Fabricate and label boilers to comply with ASME Boiler and Pressure Vessel Code.
- C. ASHRAE/IES 90.1 Compliance: Boilers shall have minimum efficiency in accordance with Table 6.8.1-6 and other requirements in Ch. 6 of ASHRAE/IES 90.1.
- D. ASHRAE 90.2 Compliance: Boilers shall have minimum efficiency in accordance with Ch. 6 of ASHRAE 90.2.
- E. DOE Compliance: Minimum efficiency shall comply with 10 CFR 431, Subpart E, Appendix N.
- F. Mounting Base: For securing boiler to concrete base.
 - 1. Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler pressure vessel, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Section 230548 "Vibration and Seismic Controls for HVAC" when mounting base is anchored to building structure.

2.2 FLOOR-MOUNTED, FORCED-DRAFT, FIRE-TUBE CONDENSING BOILERS

- A. Manufacturers: Subject to compliance with requirements, undefined:
 - 1. AERCO; A WATTS Brand.
 - 2. Cleaver-Brooks.
 - 3. Lochinvar, LLC.
- B. Description: Factory-fabricated, -assembled, and -tested, fire-tube, forced-draft, condensing boiler with heat exchanger sealed pressure tight, built on a steel base, including insulated jacket; flue-gas vent; combustion-air intake connections; water supply, return, and condensate drain connections; and controls. Units are to be for water-heating service only.
- C. Heat Exchanger: Corrosion-resistant Type 316 stainless steel.
- D. Combustion Chamber and Flue Pipes: Corrosion-resistant stainless steel.

- E. Pressure Vessel: Carbon steel with welded heads and tube connections.
- F. Burner: Natural gas , forced draft.
- G. Blower: Centrifugal fan to operate during each burner-firing sequence and to prepurge and postpurge the combustion chamber.
 - 1. Motors: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - a. Motor Sizes: Large enough so driven load will not require motor to operate in service factor range above 1.0.
- H. Gas Train: Combination gas valve with manual shutoff and pressure regulator.
- I. Ignition: Direct-spark ignition or silicone carbide hot-surface ignition with 100 percent main-valve shutoff and electronic flame supervision.
- J. Casing:
 - 1. Jacket: Sheet metal , with snap-in or interlocking closures.
 - 2. Control Compartment Enclosures: NEMA 250, Type 1A.
 - 3. Finish: Baked-enamel Powder-coated Stainless steel protective finish.
 - 4. Insulation: Minimum 2-inch- thick, mineral-fiber polyurethane-foam insulation surrounding the heat exchanger.
 - 5. Combustion-Air Connections: Inlet and vent duct collars.

2.3 TRIM - FOR HOT-WATER BOILERS

- A. Include devices sized to comply with ASME B31.9.
- B. Aquastat Controllers: Operating , firing rate, and high limit with manual reset.
- C. Alarm bell with silence switch.
- D. Boiler Air Vent: Manual.
- E. Drain Valve: Minimum NPS 3/4 hose-end gate valve.

2.4 CONTROLS

- A. Boiler operating controls shall include the following devices and features:
 - 1. Control transformer.
 - 2. Set-Point Adjust: All set points shall be adjustable.
 - 3. Electric, factory-fabricated and factory-installed panel to modulate burner and control burner-firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
 - a. Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.

4. Electric, factory-fabricated and panel to control burner-firing rate, to reset supply-water temperature inversely with outside-air temperature. At outside-air temperature, set supply-water temperature at outside-air temperature, set supply-water temperature at.
 - a. Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.
- B. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
 1. High Cutoff: Manual reset stops burner if operating conditions rise above maximum boiler design temperature.
 2. Low-Water Cutoff Switch: Electronic probe shall prevent burner operation on low water. Cutoff switch shall be manual -reset type.
 3. Blocked Inlet Safety Switch: Manual-reset pressure switch factory mounted on boiler combustion-air inlet.
 4. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.
- C. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.
 1. Hardwired Points:
 - a. Monitoring: On/off status, common trouble alarm low-water-level alarm.
 - b. Control: On/off operation, hot-water-supply temperature set-point adjustment.
 2. A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. All monitoring and control features, which are available at the local boiler control panel, shall also be available at the remote operator workstation through the building automation system.

2.5 ELECTRICAL POWER

- A. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are shown on Drawings and specified in electrical Sections.
- B. Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.
 1. House in NEMA 250, Type 1 enclosure.
 2. Wiring shall be numbered and color coded to match wiring diagram.
 3. Install factory wiring outside of an enclosure in a metal raceway.
 4. Field power interface shall be to.
 5. Provide branch power circuit to each motor and to controls with a disconnect switch or circuit breaker.
 6. Provide each motor with overcurrent protection.

2.6 VENTING KITS

- A. Kit: Complete system, ASTM A959, Type 29-4C stainless steel pipe, vent terminal, thimble, indoor plate, vent adapter, condensate trap and dilution tank, and sealant.

- B. Combustion-Air Intake: Complete system, stainless steel pipe, vent terminal with screen, inlet air coupling, and sealant.

2.7 CONDENSATE-NEUTRALIZATION UNITS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Neutra-Safe Corporation.
 - 2. SFA Saniflo USA.
 - 3. Skidmore Pump.
 - 4. Wessels Company.
- B. Description: Factory-fabricated and -assembled condensate-neutralizing tank assembly of corrosion-resistant plastic material with threaded or flanged inlet and outlet pipe connections. Device functions to prevent acidic condensate from damaging grain system. It is to be piped to receive acidic condensate discharged from condensing boiler and neutralize it by chemical reaction with replaceable neutralizing agent. Neutralized condensate is then piped to suitable drain.
- C. Tank features:
 - 1. All corrosion-resistant material.
 - 2. Suitable for use on all natural gas and propane boilers.
 - 3. Includes initial charge of neutralizing agent.
 - 4. Neutralizing agent to be easily replaceable when exhausted.
 - 5. Inlet and outlet pipe connections.
- D. Capsule Configuration:
 - 1. Low-profile design for applications where boiler condensate drain is close to the floor.
 - 2. Easily removed and opened for neutralizing agent replacement.
 - 3. Multiple units may be used for larger capacity.
- E. Tank Configuration:
 - 1. Utilized where boiler is elevated or where tank is installed in a pit with tank top flush with floor.
 - 2. Top easily removed for neutralizing agent replacement.
 - 3. Internal baffles to channel flow for complete neutralization.
 - 4. Integral bypass to prevent condensate backflow into appliance.
 - 5. Multiple units may be used for larger capacity.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting performance of the Work.
 - 1. Final boiler locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- B. Examine mechanical spaces for suitable conditions where boilers will be installed.

- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 BOILER INSTALLATION

A. Equipment Mounting:

1. Install floor-mounted boilers on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
2. Install wall-hung boilers where indicated on Drawings using suitable hangers. Comply with manufacturer's mounting instructions.
3. Comply with requirements for vibration isolation and seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
4. Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

- B. Install gas-fired boilers according to NFPA 54.
- C. Assemble and install boiler trim.
- D. Install electrical devices furnished with boiler but not specified to be factory mounted.
- E. Install control wiring to field-mounted electrical devices.

3.3 PIPING CONNECTIONS

- A. Comply with requirements for hydronic piping specified in Section 232113 "Hydronic Piping."
- B. Drawings indicate general arrangement of piping, fittings, and specialties.
- C. When installing piping adjacent to boiler, allow space for service and maintenance of condensing boilers. Arrange piping for easy removal of condensing boilers.
- D. Install condensate drain piping to condensate-neutralization unit and from neutralization unit to nearest floor drain. Piping shall be at least full size of connection. Install piping with a minimum of 2 percent downward slope in direction of flow.
- E. Install condensate piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Install piping with a minimum of 2 percent downward slope in direction of flow.
- F. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas-train connection. Provide a reducer if required.
- G. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve, and union or flange at each connection.
- H. Install piping from safety relief valves to nearest floor drain.

3.4 DUCT CONNECTIONS

A. Boiler Venting:

1. Install flue-venting kit and combustion-air intake.
2. Comply with all boiler manufacturer's installation instructions.
3. Field fabricate and install boiler vent and combustion-air intake.
4. Utilize vent and intake duct material, size, and configuration as indicated in boiler manufacturer's instructions and to comply with UL 1738.
5. Comply with all boiler manufacturer's installation instructions.
6. Connect boiler vent full size to boiler connections.
7. Comply with requirements in Section 235123 "Gas Vents."
8. Comply with all boiler manufacturer's installation instructions.

3.5 ELECTRICAL CONNECTIONS

- A. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- C. Install electrical devices furnished by manufacturer, but not factory mounted, according to NFPA 70 and NECA 1.
- D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.
 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
 2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least high.

3.6 CONTROL CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.
- B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."
- C. Install nameplate for each control connection, indicating field control panel designation and I/O control designation feeding connection.
 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
 2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least high.

3.7 FIELD QUALITY CONTROL

- A. Perform tests and inspections with the assistance of a factory-authorized service representative:

B. Tests and Inspections:

1. Perform installation and startup checks in accordance with manufacturer's written instructions.
2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
3. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - a. Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and water temperature.
 - b. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

C. Boiler will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

E. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion , provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

3.8 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain boilers. Refer to Section 017900 "Demonstration and Training." Video record the training sessions and provide electronic copy to Owner.

1. Instructor shall be factory trained and certified.
2. Provide not less than hours of training.
3. Train personnel in operation and maintenance and to obtain maximum efficiency in plant operation.
4. Provide instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.
5. Obtain Owner sign-off that training is complete.
6. Owner training shall be held at Project site.

END OF SECTION 235216

SECTION 236423.13 - AIR-COOLED, SCROLL WATER CHILLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes packaged, air-cooled, electric-motor-driven, scroll water chillers.

1.3 DEFINITIONS

- A. BAS: Building automation system.
- B. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
- C. DDC: Direct digital control.
- D. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in Btu/h to the total power input given in watts at any given set of rating conditions.
- E. GFI: Ground fault interrupt.
- F. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit for a single chiller calculated per the method defined by AHRI 550/590 and referenced to AHRI standard rating conditions.
- G. I/O: Input/output.
- H. kW/Ton: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons at any given set of rating conditions.
- I. NPLV: Nonstandard part-load value. A single number part-load efficiency figure of merit for a single chiller calculated per the method defined by AHRI 550/590 and intended for operating conditions other than the AHRI standard rating conditions.
- J. SCCR: Short-circuit current rating.
- K. TEAO: Totally enclosed air over.
- L. TENV: Totally enclosed nonventilating.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include refrigerant, rated capacities, operating characteristics, and furnished specialties and accessories.
 - 2. Performance at AHRI standard conditions and at conditions indicated.
 - 3. Performance at AHRI standard unloading conditions.
 - 4. Minimum evaporator flow rate.
 - 5. Refrigerant capacity of water chiller.
 - 6. Oil capacity of water chiller.
 - 7. Fluid capacity of evaporator.
 - 8. Characteristics of safety relief valves.
 - 9. Force and moment capacity of each piping connection.
- B. Shop Drawings: Complete set of manufacturer's prints of water chiller assemblies, control panels, sections and elevations, and unit isolation. Include the following:
 - 1. Assembled unit dimensions.
 - 2. Weight and load distribution.
 - 3. Required clearances for maintenance and operation.
 - 4. Size and location of piping and wiring connections.
 - 5. Diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings:
 - 1. Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - a. Structural supports.
 - b. Piping roughing-in requirements.
 - c. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
 - d. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.
 - 2. Each view to show screened background with the following:
 - a. Column grids, beams, columns, and concrete housekeeping pads.
 - b. Layout with walls, floors, and roofs, including each room name and number.
 - c. Equipment and products of other trades that are located in vicinity of chillers and part of final installation, such as plumbing systems.
- B. Certificates: For certification required in "Quality Assurance" Article.
- C. Installation instructions.
- D. Source quality-control reports.
- E. Startup service reports.
- F. Sample Warranty: For special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each water chiller to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

- A. AHRI Certification: Certify chiller according to AHRI 590 certification program.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Ship water chillers from the factory fully charged with refrigerant and filled with oil.
- B. Package water chiller for export shipping.

1.9 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of water chillers that fail in materials or workmanship within specified warranty period.
 - 1. Extended warranties include, but are not limited to, the following:
 - a. Complete chiller including refrigerant and oil charge.
 - b. Complete compressor and drive assembly including refrigerant and oil charge.
 - c. Refrigerant and oil charge.
 - 1) Loss of refrigerant charge for any reason due to manufacturer's product defect and product installation.
 - d. Parts and labor.
 - 2. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Site Altitude: Chiller shall be suitable for altitude at which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.
- B. AHRI Rating: Rate water chiller performance according to requirements in AHRI 550/590.
- C. ASHRAE Compliance: ASHRAE 15 for safety code for mechanical refrigeration.
- D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- E. ASME Compliance: Fabricate and stamp water chiller heat exchangers to comply with ASME Boiler and Pressure Vessel Code.

- F. Comply with NFPA 70.
- G. Comply with requirements of UL 1995, "Heating and Cooling Equipment," and include label by a qualified testing agency showing compliance.
- H. Operation Following Loss of Normal Power:
 - 1. Equipment, associated factory- and field-installed controls, and associated electrical equipment and power supply connected to backup power system shall automatically return equipment and associated controls to the operating state occurring immediately before loss of normal power without need for manual intervention by an operator when power is restored either through a backup power source, or through normal power if restored before backup power is brought on-line.
 - 2. See drawings for equipment served by backup power systems.
 - 3. Provide means and methods required to satisfy requirement even if not explicitly indicated.
- I. Outdoor Installations:
 - 1. Chiller shall be suitable for outdoor installation indicated. Provide adequate weather protection to ensure reliable service life over a 25 -year period with minimal degradation due to exposure to outdoor ambient conditions.
 - 2. Chillers equipped to provide safe and stable operation while achieving performance indicated when operating at extreme outdoor temperatures encountered by the installation. Review historical weather database and provide equipment that can operate at extreme outdoor temperatures recorded over past 30 -year period.

2.2 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Daikin Applied.
 - 2. Trane.
 - 3. YORK; brand of Johnson Controls International plc, Building Solutions North America.

2.3 MANUFACTURED UNITS

- A. Description: Factory-assembled and run-tested water chiller complete with compressor(s), compressor motors and motor controllers, evaporator, condenser with fans, electrical power, controls, and indicated accessories.
- B. Security Package: Security grilles with fasteners for additional protection of compressors, evaporator, and condenser coils. Grilles shall be coated for corrosion resistance and shall be removable for service access.

2.4 CABINET

- A. Base: Galvanized-steel base extending the perimeter of water chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit.
- B. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly supported from base.
- C. Casing: Galvanized steel.

- D. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a 500 - hour salt-spray test according to ASTM B117.

2.5 COMPRESSOR-DRIVE ASSEMBLIES

A. Compressors:

1. Description: Positive-displacement direct drive with hermetically sealed casing.
2. Each compressor provided with suction and discharge service valves, crankcase oil heater, and suction strainer.
 - a. For multiple compressor assemblies, it is acceptable to isolate each compressor assembly in lieu of each compressor.
3. Operating Speed: Nominal 3600 rpm for 60-Hz applications.
4. Capacity Control: On-off compressor cycling , plus hot-gas bypass.
 - a. Operating Range: From 100 to 10 percent of design capacity.
 - b. Digital compressor unloading is an acceptable alternative to achieve capacity control.
5. Oil Lubrication System: Automatic pump with strainer, sight glass, filling connection, filter with magnetic plug or removable magnet in sump, and initial oil charge.
 - a. Manufacturer's other standard methods of providing positive lubrication are acceptable in lieu of an automatic pump.

B. Compressor Motors:

1. Hermetically sealed and cooled by refrigerant suction gas.
2. High-torque, two-pole induction type with inherent thermal-overload protection on each phase.

C. Compressor Motor Controllers:

1. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing.

2.6 REFRIGERATION

A. Refrigerant: R-410A. Classified as Safety Group A1 according to ASHRAE 34.

B. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.

C. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line and the refrigerant liquid-line to allow the isolation and storage of the refrigerant charge in the chiller condenser.

1. For multiple compressor assemblies, it is acceptable to isolate each compressor assembly in each circuit in lieu of each compressor.

D. Pressure Relief Device:

1. Comply with requirements in ASHRAE 15, ASHRAE 147, and applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

2. Select and configure pressure relief devices to protect against corrosion and inadvertent release of refrigerant.
3. ASME-rated, spring-loaded, pressure relief valve; single- or multiple-seating type. Pressure relief valve(s) shall be provided for each heat exchanger.

2.7 AIR-COOLED CONDENSER

- A. Coil(s) with integral subcooling on each circuit.
- B. Copper Tube with Plate Fin Coils:
 1. Construct coils of copper tubes mechanically bonded to aluminum fins.
 2. Coating: None .
- C. Aluminum Microchannel Coils:
 1. Series of flat tubes containing a series of multiple, parallel-flow microchannels layered between refrigerant header manifolds.
 2. Single- or multiple-pass arrangement.
 3. Construct fins, tubes, and header manifolds of aluminum alloy treated with a corrosion-resistant coating.
- D. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.
- E. Fan Motors: TENV or TEAO enclosure, with sealed and permanently lubricated bearings, and having built-in overcurrent- and thermal-overload protection.
 1. Overcurrent- and thermal-overload protection not integral to motor is acceptable if provided with chiller electrical power package.
- F. Fan Guards: Removable steel safety guards with corrosion-resistant coating.

2.8 INSULATION

- A. Closed-cell, flexible, elastomeric thermal insulation complying with ASTM C534/C534M, Type I for tubular materials and Type II for sheet materials.
 1. Thickness: 1-1/2 inches .
- B. Adhesive: As recommended by insulation manufacturer.
- C. Factory-applied insulation over all cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.
 1. Apply adhesive to 100 percent of insulation contact surface.
 2. Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
 3. Seal seams and joints to provide a vapor barrier.
 4. After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

5. Manufacturer has option to factory or field insulate chiller components to reduce potential for damage during installation.
6. Field-Applied Insulation:
 - a. Components that are not factory insulated shall be field insulated to comply with requirements indicated.
 - b. Manufacturer shall be responsible for chiller insulation whether factory or field installed to ensure that manufacturer is the single point of responsibility for chillers.
 - c. Manufacturer's factory-authorized service representative shall instruct and supervise installation of field-applied insulation.
 - d. After field-applied insulation is complete, paint insulation to match factory-applied finish.

2.9 ELECTRICAL

- A. Factory installed and wired, and functionally tested at factory before shipment.
- B. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to water chiller.
- C. House in a unit-mounted, NEMA 250, Type 3R enclosure with hinged access door with lock and key or padlock and key.
- D. Wiring shall be numbered and color-coded to match wiring diagram.
- E. Factory wiring shall be located outside of an enclosure in a metal raceway. Terminal connections shall be made with not more than a 24-inch length of liquidtight conduit.
- F. Field power interface shall be to or non-automatic circuit breaker. Minimum SCCR according to UL 508 shall be as required by electrical power distribution system, but not less than 42,000 A.
- G. Each motor shall have overcurrent protection.
- H. Overload relay sized according to UL 1995, or an integral component of water chiller control microprocessor.
- I. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.
- J. Controls Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
- K. Control Relays: Auxiliary and adjustable time-delay relays, or an integral to water chiller microprocessor.
- L. Service Receptacle:
 1. Unit-mounted, 120-V GFI duplex receptacle.
 2. Power receptacle from chiller internal electrical power wiring.
- M. Indicate the following for water chiller electrical power supply:
 1. Current, phase to phase, for all three phases.
 2. Voltage, phase to phase and phase to neutral for all three phases.
 3. Three-phase real power (kilowatts).
 4. Three-phase reactive power (kilovolt amperes reactive).
 5. Power factor.

6. Running log of total power versus time (kilowatt hours).
7. Fault log, with time and date of each.

2.10 CONTROLS

- A. Factory installed and wired, and functionally tested at factory before shipment.
- B. Standalone, microprocessor based, with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.
- C. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.
- D. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, digital display. Display the following:
 1. Date and time.
 2. Operating or alarm status.
 3. Operating hours.
 4. Outside-air temperature if required for chilled-water reset.
 5. Temperature and pressure of operating set points.
 6. Chilled-water entering and leaving temperatures.
 7. Refrigerant pressures in evaporator and condenser.
 8. Saturation temperature in evaporator and condenser.
 9. Elapsed time meter (compressor run status).
 10. Percent of maximum motor amperage.
 11. Superheat.
- E. Control Functions:
 1. Manual or automatic startup and shutdown time schedule.
 2. Capacity control based on evaporator leaving-fluid temperature.
 3. Capacity control compensated by rate of change of evaporator entering-fluid temperature.
 4. Chilled-water entering and leaving temperatures, control set points, and motor load limit. Chilled-water leaving temperature shall be reset based on return-water temperature.
 5. Current limit and demand limit.
 6. Condenser-water temperature.
 7. External water chiller emergency stop.
 8. Antirecycling timer.
 9. Automatic lead-lag switching.
- F. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
 1. Low evaporator pressure or high condenser pressure.
 2. Low chilled-water temperature.
 3. Refrigerant high pressure.
 4. High or low oil pressure.
 5. High oil temperature.
 6. Loss of chilled-water flow.
 7. Loss of condenser-water flow.
 8. Control device failure.

- G. DDC System Interface: Factory-install hardware and software to enable system to monitor, control, and display chiller status and alarms.
 - 1. Communication Interface: ASHRAE 135 (BACnet) communication interface shall enable control system operator to remotely control and monitor the water chiller from an operator workstation. Control features and monitoring points displayed locally at water chiller control panel shall be available through DDC system for HVAC.
- H. Factory-installed wiring outside of enclosures shall be in NFPA 70-complaint raceway. Make terminal connections with liquidtight or flexible metallic conduit.

2.11 ACCESSORIES

- A. Enclosures: factory-mounted louvered panels which shall completely screen from view and protect condenser coils, evaporators, and compressors.

2.12 MATERIALS

- A. Steel:
 - 1. ASTM A36/A36M for carbon structural steel.
 - 2. ASTM A568/A568M for steel sheet.
- B. Stainless Steel:
 - 1. Manufacturer's standard grade for casing.
 - 2. Manufacturer's standard type, ASTM A240/A240M for bare steel exposed to airstream or moisture.
- C. Galvanized Steel: ASTM A653/A653M.
- D. Aluminum: ASTM B209.
- E. Comply with Section 230546 "Coatings for HVAC" for corrosion-resistant coating.
- F. Corrosion-Resistant Coating: Coat with a corrosion-resistant coating capable of withstanding a 3000 - hour salt-spray test according to ASTM B117.
 - 1. Standards:
 - a. ASTM B117 for salt spray.
 - b. ASTM D2794 for minimum impact resistance of 100 in-lb
 - c. ASTM B3359 for cross hatch adhesion of 5B.
 - 2. Application: Immersion .
 - 3. Thickness: 1 mil .
 - 4. Gloss: Minimum gloss of 60 on a 60-degree meter.

2.13 SOURCE QUALITY CONTROL

- A. Perform functional test of water chillers before shipping.

- B. Factory performance test water chillers, before shipping, according to AHRI 550/590.
 - 1. Test the following conditions:
 - a. Design conditions indicated.
 - b. AHRI 550/590 part-load points.
 - 2. Allow Owner access to place where water chillers are being tested. Notify Owner 30 days in advance of testing.
- C. Factory test and inspect evaporator according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Stamp with ASME label.
- D. For water chillers located outdoors, rate sound power level according to AHRI 370 procedure.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Before water chiller installation, examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, controls, and electrical connections to verify actual locations, sizes, and other conditions affecting water chiller performance, maintenance, and operations.
 - 1. Water chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping, controls, and electrical connections.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 WATER CHILLER INSTALLATION

- A. Coordinate sizes and locations of bases with actual equipment provided. Cast anchor-bolt inserts into concrete bases.
- B. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures with actual equipment provided.
- C. Install water chillers on support structure indicated.
- D. Equipment Mounting:
 - 1. Install water chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."
- E. Maintain manufacturer's recommended clearances for service and maintenance.
- F. Maintain clearances required by governing code.
- G. Chiller manufacturer's factory-trained service personnel shall charge water chiller with refrigerant if not factory charged and fill with oil if not factory installed.

- H. Install separate devices furnished by manufacturer and not factory installed.
 - 1. Chillers shipped in multiple major assemblies shall be field assembled by chiller manufacturer's factory-trained service personnel.

3.3 PIPING CONNECTIONS

- A. Comply with requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Comply with requirements in Section 232300 "Refrigerant Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- C. Where installing piping adjacent to chillers, allow space for service and maintenance.
- D. Evaporator Fluid Connections:
 - 1. Connect to evaporator inlet with shutoff valve, strainer, flexible connector, thermometer, and plugged tee with pressure gage.
 - 2. Connect to evaporator outlet with shutoff valve, balancing valve, flexible connector, flow switch, thermometer, plugged tee with pressure gage, flow meter, and drain connection with valve.
 - 3. Make connections to water chiller with a flange or mechanical coupling.
- E. Connect each drain connection with a drain valve, full size of drain connection. Connect drain pipe to drain valve with union and extend drain pipe to terminate over floor drain.
- F. Connect each chiller vent connection with an automatic vent, full size of vent connection.

3.4 ELECTRICAL POWER CONNECTIONS

- A. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- C. Provide nameplate for each electrical connection indicating electrical equipment designation and circuit number feeding connection. Nameplate shall be laminated phenolic layers of black with engraved white letters at least 1/2 inch high. Locate nameplate where easily visible.

3.5 CONTROLS CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.
- B. Connect control wiring between chillers and other equipment to interlock operation as required to provide a complete and functioning system.
- C. Connect control wiring between chiller control interface and DDC system for remote monitoring and control of chillers. Comply with requirements in Section 230923 "Direct Digital Control (DDC) System for HVAC."
- D. Provide nameplate on face of chiller control panel indicating control equipment designation serving chiller and the I/O point designation for each control connection. Nameplate shall be laminated phenolic layers of black with engraved white letters at least 1/2 inch high.

3.6 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.
- B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.
- C. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
 - 1. Verify that refrigerant charge is sufficient and water chiller has been leak tested.
 - 2. Verify that pumps are installed and functional.
 - 3. Verify that thermometers and gages are installed.
 - 4. Operate water chiller for run-in period.
 - 5. Check bearing lubrication and oil levels.
 - 6. Verify that refrigerant pressure relief device for chillers installed indoors is vented outside.
 - 7. Verify proper motor rotation.
 - 8. Verify and record performance of chilled-water flow and low-temperature interlocks.
 - 9. Verify and record performance of water chiller protection devices.
 - 10. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
- D. Visually inspect chiller for damage before starting. Repair or replace damaged components, including insulation. Do not start chiller until damage that is detrimental to operation has been corrected.
- E. Prepare a written startup report that records results of tests and inspections.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain water chillers. Video record the training sessions and provide electronic copy to Owner.
 - 1. Instructor shall be factory trained and certified.
 - 2. Provide not less than eight hours of training.
 - 3. Train personnel in operation and maintenance and to obtain maximum efficiency in plant operation.
 - 4. Provide instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.
 - 5. Obtain Owner sign-off that training is complete.
 - 6. Owner training shall be held at Project site.

END OF SECTION 236423.13

SECTION 237223.23 - PACKAGED, OUTDOOR, HEAT WHEEL ENERGY RECOVERY UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.1 SUMMARY

- B. Section Includes:

- 1. Heat wheels in packaged, outdoor, total energy-recovery units.

- C. Related Requirements:

- 1. Section 237343.16 "Outdoor, Semi-Custom Air-Handling Units" for outdoor, semi-custom air-handling units if they also include coils, other than electric coils for frost control, in addition to heat wheels.

1.2 ACTION SUBMITTALS

- A. Product Data: For each type of product.

- 1. Include packaged, outdoor, heat-wheel, energy-recovery-unit rated capacities, operating characteristics, furnished specialties, and accessories.
 - 2. Fans:
 - a. Certified fan-performance curves with system operating conditions indicated.
 - b. Certified fan-sound power ratings.
 - c. Fan construction and accessories.
 - d. Motor ratings, electrical characteristics, and motor accessories.

- B. Shop Drawings: For packaged, outdoor, heat-wheel, energy-recovery units.

- 1. Include plans, elevations, sections, details, and mounting details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, lifting requirements, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.

- C. Delegated-Design Submittal: For packaged, outdoor, heat-wheel, energy-recovery units indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by qualified professional engineer responsible for their preparation.

- 1. Detail fabrication and assembly of heat-wheel, energy-recovery equipment.
 - 2. Vibration-Isolation Roof Curb Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include rails and frames for equipment mounting.

3. Design Calculations: Calculate requirements for selecting vibration isolators and for designing vibration-isolation roof curbs.

1.3 COORDINATION

- A. Coordinate sizes and locations of building openings and duct connections with actual equipment provided.

1.4 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of packaged, outdoor, heat-wheel, energy-recovery units that fail in materials or workmanship within specified warranty period.
 1. Warranty Period for Packaged Energy-Recovery Units: One years from date of Substantial Completion.
 2. Warranty Period for Energy-Recovery Wheel: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.
- B. ASHRAE Compliance:
 1. Applicable requirements in ASHRAE 62.1.
 2. Capacity ratings for heat-wheel, energy-recovery equipment: Comply with ASHRAE 84.
- C. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1.
- D. Comply with ASTM E84 or UL 723.

2.2 CAPACITIES AND CHARACTERISTICS

- A. Type: Heat-wheel total energy-recovery unit.
- B. Refer to Equipment Schedules on drawings for unit and component capacities and requirements.

2.3 PACKAGED, OUTDOOR, HEAT-WHEEL, ENERGY-RECOVERY UNITS

- A. Source Limitations: Obtain packaged, outdoor, heat-wheel, energy-recovery units from single manufacturer.
- B. Surfaces in Contact with Airstream: Comply with requirements in ASHRAE 62.1.
- C. Housing: Manufacturer's standard construction with corrosion-protection coating and exterior finish, gasketed hinged access doors with neoprene gaskets for inspection and access to internal parts, minimum 2 inches thick, thermal insulation, knockouts for electrical connections, exterior drain connection, and lifting lugs.

D. Heat Wheel:

1. Casing:
 - a. Manufacturer's standard construction with standard factory finish.
 - b. Slide-in, slide-out cassette style.
 - c. Provide casing seals on periphery of rotor and on duct divider and purge section.
 - d. Support vertical rotors on grease-lubricated ball bearings having extended grease fittings or permanently lubricated bearings with minimum L-50 of 200,000 hours. Support horizontal rotors on tapered roller bearing.
2. Rotor: Aluminum, metallic, segmented wheel, strengthened with radial spokes impregnated with nonmigrating, water-selective, four-angstrom, molecular-sieve desiccant coating.
3. Drive: Electric motor, with speed changed by variable-frequency motor controller and self-adjusting multilink belt around outside of rotor.
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

E. Supply and Exhaust Fans: Centrifugal, forward-curved fan with spring isolators of 1-inch static deflection.

1. Motor and Drive: Direct driven, with speed changed by variable-frequency motor controller.
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - b. Motor Sizes: Minimum size as indicated. If size is not indicated, provide motor large enough so driven load will not require motor to operate in service factor range above 1.0.

F. Filters:

1. Description: pleated, factory-fabricated, self-supported, disposable air filters with holding frames.
2. UL Compliance: Comply with UL 900.
3. Media: Interlaced glass fibers sprayed with nonflammable adhesive and antimicrobial coating.
4. Filter Media Frame: Beverage board with perforated metal retainer or metal grid on outlet side.
5. Filter-Mounting Frames: Arranged with access doors or panels on one or both sides of unit. Design unit with filters removable from one side or lift out from access plenum.

G. Wiring: Fabricate units with space within housing for electrical conduits. Wire motors and controls, so only external connections are required during installation.

1. Outdoor Enclosure: NEMA 250, Type 3R enclosure contains relays, starters, and terminal strip.
2. Include nonfused disconnect switches.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

- B. Examine casing insulation materials and filter media before packaged, outdoor, heat wheel energy-recovery unit installation. Replace insulation materials and filter media that are wet, moisture damaged, or mold contaminated.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION OF PACKAGED, OUTDOOR, HEAT-WHEEL, ENERGY-RECOVERY UNITS

- A. Install packaged, outdoor, heat-wheel, energy-recovery units, so supply and exhaust airstreams flow in opposite directions, and rotation is away from exhaust side to purge section to supply side.
 - 1. Install access doors in both supply and exhaust ducts, both upstream and downstream, for access to wheel surfaces, drive motor, and seals.
 - 2. Install removable panels or access doors between supply and exhaust ducts on building side for bypass during startup.
 - 3. Access doors and panels are specified in Section 233300 "Air Duct Accessories."
- B. Equipment Mounting:
 - 1. Install roof-mounted packaged, outdoor, heat-wheel, energy-recovery units on manufacturer's-recommended-height equipment roof curbs. Comply with requirements for equipment curbs specified in Section 077200 "Roof Accessories."
 - 2. Comply with requirements for vibration-isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
 - 3. Comply with requirements for vibration-isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."
- C. Install units with clearances for service and maintenance.
- D. Do not operate equipment fans until temporary or permanent filters are in place. Replace temporary filters used during construction and testing with new, clean filters prior to final inspection.

3.3 DUCTWORK CONNECTIONS

- A. Comply with requirements for ductwork in accordance with Section 233113 "Metal Ducts."

3.4 PIPING CONNECTIONS

- A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to unit, allow service and maintenance.
- C. Condensate Drain Piping: See Section 232113 "Hydronic Piping" for pipe type. Install condensate drain piping from drain pans to nearest floor drain, same size as condensate drain connection.
 - 1. Construct deep trap at connection to drain pan, and install cleanouts at changes in direction.

3.5 ELECTRICAL CONNECTIONS

- A. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.
- B. Connect wiring in accordance with Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- C. Ground equipment in accordance with Section 260526 "Grounding and Bonding for Electrical Systems."
- D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.
 - 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
 - 2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.6 CONTROL CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.
- B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."

3.7 STARTUP SERVICE

- A. Engage factory-authorized service representative to perform startup service.
 - 1. Complete installation and startup checks in accordance with manufacturer's written instructions.

3.8 ADJUSTING

- A. Adjust moving parts to function smoothly and lubricate as recommended by manufacturer.
- B. Adjust initial temperature and humidity set points.
- C. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

END OF SECTION 237223.23

SECTION 237343.16 - OUTDOOR, SEMI-CUSTOM AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes outdoor, semi-custom air-handling units that are factory assembled using multiple section components; including:
 - 1. Unit casings.
 - 2. Fan, drive, and motor section.
 - 3. Coil section.
 - 4. Air filtration section.
 - 5. Dampers.
 - 6. Humidifiers.
 - 7. UV-C lamp systems.
 - 8. Roof curbs.

1.3 ACTION SUBMITTALS

- A. Product Data: For each air-handling unit.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
 - 3. Include unit dimensions and weight.
 - 4. Include cabinet material, metal thickness, finishes, insulation, and accessories.
 - 5. Fans:
 - a. Include certified fan-performance curves with system operating conditions indicated.
 - b. Include certified fan-sound power ratings.
 - c. Include fan construction and accessories.
 - d. Include motor ratings, electrical characteristics, and motor accessories.
 - 6. Include certified coil-performance ratings with system operating conditions indicated.
 - 7. Include dampers, including housings, linkages, and operators.
- B. Shop Drawings: For each outdoor, semi-custom air-handling unit.
 - 1. Include plans, elevations, sections, and mounting details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Detail fabrication and assembly of outdoor, semi-custom air-handling units, as well as procedure and diagrams.

4. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans and other details, or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.
- B. Seismic Qualification Data: Certificates for air-handling units, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
 4. Restraint of internal components.
- C. Wind Qualification Data: Certificates for air-handling units, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculations.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of wind force and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- D. Source quality-control reports.
- E. Startup service reports.
- F. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Filters: One set(s) for each air-handling unit.
 2. Gaskets: One set(s) for each access door.
 3. Fan Belts: One set(s) for each air-handling unit fan.

1.7 WARRANTY

- A. Warranty: Manufacturer agrees to repair or replace components of outdoor, semi-custom, air-handling unit that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period for Entire Unit: Manufacturer's standard but not less than one year(s) from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.
- C. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
- D. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
- E. Structural Performance:
 - 1. Casing Panels: Self-supporting and capable of withstanding positive/negative 8-inch wg internal static pressure, without exceeding a midpoint deflection of 0.0042 inch/inch of panel span.
 - 2. Floor and Roof Panels: Self-supporting and capable of withstanding 300-lb static load at midspan, without exceeding a midpoint deflection of 0.0042 inch/inch.
- F. Casing Leakage Performance: ASHRAE 111, Class 6 leakage or better at plus or minus 8-inch wg.

2.2 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Carrier Corporation.
 - 2. Daikin Applied.
 - 3. Trane.
 - 4. YORK; a Johnson Controls company.
- B. Source Limitations: Obtain from single source from single manufacturer.

2.3 UNIT CASINGS

- A. Frame: Modular and providing overall structural integrity without reliance on casing panels for structural support.

- B. Base Rail:
 - 1. Material: Galvanized steel.
 - 2. Height: 6 inches.
- C. Casing Joints: Hermetically sealed at each corner and around entire perimeter.
- D. Double-Wall Construction:
 - 1. Outside Casing Wall:
 - a. Material, Galvanized Steel: Minimum 16 gauge thick.
 - b. Factory Finish: Provide corrosion-resistant coating.
 - 2. Inside Casing Wall:
 - a. Material, Galvanized Steel: Solid , minimum 16 gauge thick.
- E. Roof: Cross-broken and pitched with "C" caps over joints to provide watertight seal.
- F. Piping Vestibule: Insulated with same insulation and thickness as casing, 24 inches deep by full width of piping connections.
- G. Casing Insulation:
 - 1. Materials: injected polyurethane foam insulation.
 - 2. Casing Panel R-Value: Minimum R-13.
 - 3. Insulation Thickness: 3 inches.
 - 4. Thermal Break: Provide continuity of insulation with no through-casing metal in casing walls, floors, or roofs of air-handling unit.
- H. Airstream Surfaces: Surfaces in contact with airstream shall comply with requirements in ASHRAE 62.1.
- I. Static-Pressure Classifications:
 - 1. For Unit Sections Upstream of Fans: Minus 3-inch wg.
 - 2. For Unit Sections Downstream and Including Fans: 4-inch wg.
- J. Panels, Doors, and Windows:
 - 1. Panels:
 - a. Fabrication: Formed and reinforced, double-wall and insulated panels of same materials and thicknesses as casing.
 - b. Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against airflow
 - c. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - d. Size: Large enough to allow unobstructed access for inspection and maintenance of air-handling unit's internal components. At least 24 inches wide by full height of unit casing up to a maximum height of 72 inches.
 - 2. Doors:
 - a. Fabrication: Formed and reinforced, double-wall and insulated panels of same materials and thicknesses as casing.

- b. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever latches, operable from inside and outside. Arrange doors to be opened against airflow. Provide safety latch retainers on doors so that doors do not open uncontrollably.
 - c. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - d. Size: Large enough to allow for unobstructed access for inspection and maintenance of air-handling unit's internal components. At least 24 inches wide by full height of unit casing up to a maximum height of 72 inches.
- 3. Locations and Applications:
 - a. Fan Section: Doors.
 - b. Coil Section: Panels.
 - c. Access Section: Doors.
 - d. Access Sections Immediately Upstream and Downstream of Coil Sections: Doors.
 - e. Damper Section: Doors.
 - f. Filter Section: Doors large enough to allow periodic removal and installation of filters.
 - g. Access Sections Immediately Upstream and Downstream of Filter Sections: Doors.
 - h. Mixing Section: Doors.
 - i. Humidifier Section: Doors.
- 4. Service Lights: LED vaporproof luminaire with individual switched junction box located , adjacent to each access door and panel.
 - a. Locations: Each section accessed with door or panel.
- 5. Convenience Outlets: One 20-A duplex GFCI receptacle per location with junction box located on outside casing wall.
 - a. Locations: Fan section.

K. Condensate Drain Pans:

- 1. Location: Each type of cooling coil.
- 2. Construction:
 - a. Double-wall, stainless-steel sheet with space between walls filled with foam insulation and moisture-tight seal.
- 3. Drain Connection:
 - a. Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on one end of pan.
 - b. Minimum Connection Size: NPS 2.
- 4. Slope: Minimum 0.125-in./ft. slope , to comply with ASHRAE 62.1, in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and from humidifiers and to direct water toward drain connection.
- 5. Length: Extend drain pan downstream from leaving face for distance to comply with ASHRAE 62.1.
- 6. Width: Entire width of water producing device.
- 7. Depth: A minimum of 2 inches deep.
- 8. Formed sections.
- 9. Pan-Top Surface Coating for Galvanized-Steel Drain Pans: Asphaltic waterproofing compound.
- 10. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

2.4 FAN, DRIVE, AND MOTOR SECTION

- A. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.
- B. Fans: Centrifugal, galvanized steel; mounted on solid-steel shaft.
 - 1. Shafts: With field-adjustable alignment.
 - a. Turned, ground, and polished hot-rolled steel with keyway.
 - 2. Shaft Bearings:
 - a. Prelubricated and Sealed, Ball Bearings: Self-aligning, pillow-block type with an L-50 rated life of 200,000 hours according to ABMA 9.
 - 3. Housings: Formed- and reinforced-steel panels to form curved scroll housings with shaped cutoff and spun-metal inlet bell.
 - a. Bracing: Steel angle or channel supports for mounting and supporting fan scroll, wheel, motor, and accessories.
 - 4. Housings, Plenum Fans: Steel frame and panel; fabricated without fan scroll and volute housing. Provide inlet screens for Type SWSI fans.
 - 5. Plenum Fan Arrays: Contained as defined in AHRI 430. Steel or aluminum frame with inlet cone and structural framing around each fan built into an array of multiple fans. Provide motorized dampers at each fan to prevent short circuiting of flow if one fan is not operating.
 - 6. Airfoil, Centrifugal Fan Wheels (Plenum Fan Wheels): Smooth-curved inlet flange, backplate, and hollow die-formed airfoil-shaped blades continuously welded at tip flange and backplate; steel hub riveted to backplate and fastened to shaft with setscrews.
 - 7. Mounting: For internal vibration isolation and seismic control. Factory-mount fans with manufacturer's standard restrained vibration isolation mounting devices having a minimum static deflection of 1 inch.
 - 8. Shaft Lubrication Lines: Extended to a location outside the casing.
 - 9. Flexible Connector: Factory fabricated with a fabric strip minimum 5-3/4 inches wide, attached to two strips of minimum 2-3/4-inch- wide by 0.032-inch- thick, aluminum sheets.
 - a. Flexible Connector Fabric: Glass fabric, double coated with neoprene. Fabrics, coatings, and adhesives shall comply with UL 181, Class 1.
 - 1) Fabric Minimum Weight: 26 oz./sq. yd..
 - 2) Fabric Minimum Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
 - 3) Fabric Minimum Service Temperature Range: Minus 40 to plus 200 deg F.
- C. Drive, Direct: Factory-mounted, direct drive.
- D. Motors:
 - 1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - 2. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 - 3. Enclosure Type: Totally enclosed, fan cooled.

4. Enclosure Materials: Cast iron.
5. Efficiency: Premium efficient as defined in NEMA MG 1.
6. Motor Pulleys: Adjustable pitch for use with 5 -hp motors and smaller; fixed pitch for use with motors larger than 5 hp. Select pulley size so pitch adjustment is at the middle of adjustment range at fan design conditions.
7. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.

E. Comply with Section 262923 "Variable-Frequency Motor Controllers."

2.5 COIL SECTION

A. General Requirements for Coil Section:

1. Comply with AHRI 410.
2. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
3. For multizone units, provide air deflectors and air baffles to balance airflow across coils.
4. Coils shall not act as structural component of unit.

B. Cooling Coils:

1. Chilled-Water Coil: Continuous circuit.
 - a. Piping Connections: Flanged , same end of coil.
 - b. Tube Material: Copper.
 - c. Tube Thickness:.0024 inches.
 - d. Fin Type: Plate.
 - e. Fin Material: Aluminum.
 - f. Fin Thickness: 0.009 inches.
 - g. Fin and Tube Joint: Mechanical bond.
 - h. Headers:
 - 1) Seamless copper tube with brazed joints, prime coated.
 - 2) Provide insulated cover to conceal exposed outside casings of headers.
 - i. Frames: Channel frame, 0.052-inch- thick, galvanized steel.
 - j. Coatings: Corrosion-resistant coating.
 - k. Working-Pressure Ratings: Equal to the specified pressure rating of the piping system in which this coil is installed.

2.6 AIR FILTRATION SECTION

A. Side-Access Filter Mounting Frames:

1. Particulate Air Filter Frames: Match inner casing and outer casing material, and insulation thickness. Galvanized steel track.
 - a. Sealing: Incorporate positive-sealing device to ensure seal between gasketed material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.

2.7 DAMPERS

- A. Dampers: Comply with requirements in Section 230923.12 "Control Dampers."
- B. Damper Operators: Comply with requirements in Section 230923.12 "Control Dampers."
- C. Mixing Section: Multiple-blade, air-mixer assembly located immediately downstream of mixing section.

2.8 HUMIDIFIERS

- A. Self-contained humidifiers are specified in Section 238413.29 "Self-Contained Humidifiers."

2.9 UV-C LAMP SYSTEMS

- A. Description:
 - 1. UV-C lamp system consisting of power supply, power supply housing, wiring, UV lamp(s), lamp plug, lamp plug protector, encapsulated lamp, and lamp holder used for UV germicidal irradiation of cooling coil and condensate drain pan.
 - 2. Factory installed and preengineered.
- B. Standard: UL Category Code ABQK, HVAC accessories, air-duct mounted.
- C. Lamps: High output, hot cathode.
- D. Lamp-Holder Construction:
 - 1. UV- and moisture-resistant materials and designed to connect the lamp to the plug.
 - 2. Adjustable positioning.
- E. Lamp-Clamp Construction:
 - 1. UV- and moisture-resistant materials, water-tight connection.
 - 2. Adjustable positioning.
- F. Lamp Protection: Hermetically sealed to provide protection against lamp breakage and to ensure lamp contents from a broken lamp are contained.
- G. Lamp Output: UV-C energy, primarily at the 254-nm wavelength with a 360-degree energy distribution.
- H. Access Door Interlocks: Automatic disconnect on all access doors into UV-installed casing sections to shield servicing personnel from contact with light.
- I. Power Supply: UL-listed, single-point electrical connection with service disconnect.
- J. Power Consumption: Maximum of 15 W/sq. ft.

2.10 ROOF CURBS

- A. Materials: Galvanized steel with corrosion-resistant coating, watertight gaskets, and factory-installed wood nailer; complying with NRCA standards.
 - 1. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
 - a. Materials: ASTM C1071, Type I or II.
 - b. Thickness: 2 inches.
 - 2. Application: Factory applied with adhesive and mechanical fasteners to the internal surface of curb.
 - a. Liner Adhesive: Comply with ASTM C916, Type I.
 - b. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
 - c. Liner materials applied in this location shall have airstream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric depending on service air velocity.
- B. Curb Dimensions: Height of 24 inches.
- C. Wind and Seismic Restraints: Metal brackets compatible with the curb and casing, painted to match unit, used to anchor unit to the curb, and designed for loads at Project site. Comply with requirements in Section 230548 "Vibration and Seismic Controls for HVAC" for wind-load requirements.

2.11 MATERIALS

- A. Steel:
 - 1. ASTM A36/A36M for carbon structural steel.
 - 2. ASTM A568/A568M for steel sheet.
- B. Stainless Steel:
 - 1. Manufacturer's standard grade for casing.
 - 2. Manufacturer's standard type, ASTM A240/A240M for bare steel exposed to airstream or moisture.
- C. Galvanized Steel: ASTM A653/A653M.
- D. Aluminum: ASTM B209.
- E. Comply with Section 230546 "Coatings for HVAC" for corrosion-resistant coating.

2.12 SOURCE QUALITY CONTROL

- A. AHRI 430 Certification: Test, rate, and label air-handling units and their components in accordance with AHRI 430.
- B. AHRI 1060 Certification: Test, rate, and label air-handling units that include air-to-air energy recovery devices in accordance with AHRI 1060.

- C. AHRI 260 or AMCA 311 Sound Performance Rating Certification: Test, rate, and label in accordance with AHRI 260 or AMCA 311.
- D. Fan Aerodynamic Performance Rating: Test and rate fan performance for airflow, pressure, power, air density, rotation speed, and efficiency in accordance with AMCA 210.
- E. Fan Energy Index (FEI): Test in accordance with AMCA 210 and rate in accordance with AMCA 99, AMCA 207, and AMCA 208.
- F. Fan Operating Limits: Classify fans in accordance with AMCA 99, Section 14.
- G. Water Coils: Factory tested to 300 psig according to AHRI 410 and ASHRAE 33.
- H. Steam Coils: Factory tested to 300 and 200 psig underwater according to AHRI 410 and ASHRAE 33.
- I. Refrigerant Coils: Factory tested to minimum 450-psig internal pressure and to minimum 300-psig internal pressure while underwater, according to AHRI 410 and ASHRAE 33.
- J. Witnessed Casing Leakage Tests:
 - 1. Pay for all expenses, for one representative designated by Owner, to travel to the factory to witness cabinet air-leakage testing on the specific assembled unit(s) prior to release for delivery to Project site.
 - 2. If the unit(s) does not meet specified leakage requirements, perform factory modifications and retest. Do not release unit for shipment until tested leakage is measured to be within specified leakage and leakage testing report has been accepted by Owner's designated representative.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine casing insulation materials and filter media before air-handling unit installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for steam, hydronic, and condensate drainage piping systems and electrical services to verify actual locations of connections before installation.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Unit Support: Install unit level on structural curbs. Coordinate roof penetrations and flashing with roof construction. Secure units to structural support with anchor bolts. Coordinate sizes and locations of curbs with actual equipment provided.
 - 1. Comply with requirements for vibration isolation , wind-control and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."
- B. Arrange installation of units to provide access space around air-handling units for service and maintenance.

- C. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.
- D. Install filter-gauge, static-pressure taps upstream and downstream of filters. Mount filter gauges on outside of filter housing or filter plenum in accessible position. Provide filter gauges on filter banks, installed with separate static-pressure taps upstream and downstream of filters.

3.3 PIPING CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to air-handling unit, allow space for service and maintenance.
- C. Connect condensate drain pans using NPS 1-1/4 , ASTM B88, Type M copper tubing. Extend to nearest equipment or roof drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.
- D. Hot- and Chilled-Water Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.
- E. Steam and Condensate Piping: Comply with applicable requirements in Section 232213 "Steam and Condensate Heating Piping" and Section 232216 "Steam and Condensate Heating Piping Specialties." Install shutoff valve at steam supply connections, float and thermostatic trap, and union or flange at each coil return connection. Install gate valve and inlet strainer at supply connection of dry steam humidifiers, and inverted bucket steam trap to condensate return connection.
- F. Refrigerant Piping: Comply with applicable requirements in Section 232300 "Refrigerant Piping." Install shutoff valve and union or flange at each supply and return connection.

3.4 ELECTRICAL CONNECTIONS

- A. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
- B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- C. Install electrical devices furnished by manufacturer, but not factory mounted, according to NFPA 70 and NECA 1.
- D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.
 - 1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
 - 2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.5 CONTROL CONNECTIONS

- A. Install control and electrical power wiring to field-mounted control devices.

- B. Connect control wiring according to Section 260523 "Control-Voltage Electrical Power Cables."

3.6 STARTUP SERVICE

- A. Perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that zone dampers fully open and close for each zone.
7. Verify that face-and-bypass dampers provide full face flow.
8. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
9. Comb coil fins for parallel orientation.
10. Verify that proper thermal-overload protection is installed for electric coils.
11. Install new, clean filters.
12. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

- B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm.
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.

3.7 ADJUSTING

- A. Adjust damper linkages for proper damper operation.
- B. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.
- C. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

3.8 CLEANING

- A. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

3.9 FIELD QUALITY CONTROL

- A. Testing Agency: will engage a qualified testing agency to perform tests and inspections.
- B. Perform the following tests and inspections:
 - 1. Leak Test: After installation, fill water and steam coils with water, and test coils and connections for leaks.
 - 2. Charge refrigerant coils with refrigerant and test for leaks.
 - 3. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 4. HEPA Filters: Pressurize housing to a minimum of 3-inch wg or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.
 - 5. HEPA Filters, Critical Applications: Pressurize housing to a minimum of 3-inch wg or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter for air leaks according to ASME AG-1, pressure-decay method.
 - 6. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 7. Air-handling unit and components will be considered defective if unit or components do not pass tests and inspections.
 - 8. Prepare test and inspection reports.

3.10 DEMONSTRATION

- A. Train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

END OF SECTION 237343.16

SECTION 238126 - SPLIT-SYSTEM AIR-CONDITIONERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes split-system air-conditioning and heat-pump units consisting of separate evaporator-fan and compressor-condenser components.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. Include performance data in terms of capacities, outlet velocities, static pressures, sound power characteristics, motor requirements, and electrical characteristics.
- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Wiring Diagrams: For power, signal, and control wiring.

1.4 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filters: One set(s) for each air-handling unit.

1.5 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASHRAE Compliance:
 - 1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."
 - 2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Procedures," and Section 7 - "Construction and System Start-up."
- C. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1.

1.6 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork are specified in Section 033000 "Cast-in-Place Concrete."
- B. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.7 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of split-system air-conditioning units that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period:
 - a. For Compressor: Five year(s) from date of Substantial Completion.
 - b. For Parts: Five year(s) from date of Substantial Completion.
 - c. For Labor: Five year(s) from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Carrier Global Corporation.
 - 2. Daikin.
 - 3. Mitsubishi.
 - 4. Trane.
 - 5. YORK; brand of Johnson Controls International plc, Building Solutions North America.

2.2 INDOOR UNITS (5 TONS OR LESS)

- A. Wall-Mounted, Evaporator-Fan Components:
 - 1. Cabinet: Enameled steel with removable panels on front and ends in color selected by Architect, and discharge drain pans with drain connection.
 - 2. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.
 - 3. Fan: Direct drive, centrifugal.
 - 4. Fan Motors:
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
 - b. Multitapped, multispeed with internal thermal protection and permanent lubrication.
 - c. Enclosure Type: Totally enclosed, fan cooled.

- d. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.
 - e. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
 - f. Mount unit-mounted disconnect switches on exterior of unit.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
6. Condensate Drain Pans:
- a. Fabricated with one percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.
 - 1) Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
 - 2) Depth: A minimum of 1 inch deep.
 - b. Single-wall, galvanized -steel sheet.
 - c. Double-wall, -steel sheet with space between walls filled with foam insulation and moisture-tight seal.
 - d. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on one end of pan.
 - e. Pan-Top Surface Coating: Asphaltic waterproofing compound.
7. Air Filtration Section:
- a. General Requirements for Air Filtration Section:
 - 1) Comply with NFPA 90A.
 - 2) Minimum MERV according to ASHRAE 52.2.
 - 3) Filter-Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.
 - b. Disposable Panel Filters:
 - 1) Factory-fabricated, viscous-coated, flat-panel type.
 - 2) Thickness: 1 inch.
 - 3) MERV according to ASHRAE 52.2: 8.
 - 4) Media: Interlaced glass fibers sprayed with nonflammable adhesive.
 - 5) Frame: Galvanized steel, with metal grid on outlet side, steel rod grid on inlet side, and hinged; with pull and retaining handles.

2.3 OUTDOOR UNITS (5 TONS OR LESS)

A. Air-Cooled, Compressor-Condenser Components:

- 1. Casing: Steel, finished with baked enamel in color selected by Architect, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.

2. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation device. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
 - a. Compressor Type: Scroll.
 - b. Two-speed compressor motor with manual-reset high-pressure switch and automatic-reset low-pressure switch.
 - c. Refrigerant: R-407C R-410A.
 - d. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and liquid subcooler. Comply with ARI 206/110.
3. Heat-Pump Components: Reversing valve and low-temperature-air cutoff thermostat.
4. Fan: Aluminum-propeller type, directly connected to motor.
5. Motor: Permanently lubricated, with integral thermal-overload protection.
6. Low Ambient Kit: Permits operation down to 45 deg F.
7. Mounting Base: Polyethylene.

2.4 ACCESSORIES

- A. Thermostat: Wireless infrared functioning to remotely control compressor and evaporator fan, with the following features:
 1. Compressor time delay.
 2. 24-hour time control of system stop and start.
 3. Liquid-crystal display indicating temperature, set-point temperature, time setting, operating mode, and fan speed.
 4. Fan-speed selection including auto setting.
- B. Automatic-reset timer to prevent rapid cycling of compressor.
- C. Refrigerant Line Kits: Soft-annealed copper suction and liquid lines factory cleaned, dried, pressurized, and sealed; factory-insulated suction line with flared fittings at both ends.
- D. Drain Hose: For condensate.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install units level and plumb.
- B. Install evaporator-fan components using manufacturer's standard mounting devices securely fastened to building structure.
- C. Install roof-mounted, compressor-condenser components on equipment supports specified in Section 077200 "Roof Accessories." Anchor units to supports with removable, cadmium-plated fasteners.
- D. Equipment Mounting:
 1. Install ground-mounted, compressor-condenser components on polyethylene mounting base.
 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

- E. Install and connect precharged refrigerant tubing to component's quick-connect fittings. Install tubing to allow access to unit.

3.2 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where piping is installed adjacent to unit, allow space for service and maintenance of unit.

3.3 STARTUP SERVICE

- A. Perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.

END OF SECTION 238126

SECTION 238236 - FINNED-TUBE RADIATION HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes electric , finned-tube radiation heaters.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.

PART 2 - PRODUCTS

2.1 FLOOR-RECESSED ELECTRIC FINNED-TUBE RADIATION HEATERS

- A. Basis of design: Price Industries LNT (Linear Natural Convection Terminal)
- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. INDEECO.
 - 2. Price Industries.
 - 3. QMark; Marley Engineered Products.
- C. Description: Factory-packaged units constructed according to UL 499, UL 1030, and UL 2021.
 - 1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Heating Elements: SCR-controlled electric finned strip heater constructed of stainless-steel sheath material and nickel-plated fins, with high-temperature cutout and sensor running the full length of the element. Element supports shall eliminate thermal expansion noise.
 - 1. Volts:
 - 2. Phase:
 - 3. Hertz:
 - 4. Heat Output:

- E. Enclosure Style: Below floor steel plenum, minimum 20-gauge steel. Plenum shall have finished height of 10-3/8 inches and shall be suited for installation above conduit in a recessed floor cavity. Plenum shall be pedestal supported.
 - 1. Outlet Grille: Extruded-aluminum linear bar grille; pencil-proof bar spacing – refer to drawing schedules.
 - a. Mill-finish aluminum.
 - b. Anodized finish, color as selected by Architect from manufacturer's custom colors.
- F. Accessories: Integral disconnect switch, filler sections, corners, relay sections, and splice plates all matching the enclosure and grille finishes.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive finned-tube radiation heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for electrical connections to verify actual locations before installation of finned-tube radiation heaters.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 FINNED-TUBE RADIATION HEATER INSTALLATION

- A. Install units level and plumb.
- B. Install enclosure continuously around corners, using outside and inside corner fittings.
- C. Join sections with splice plates and filler pieces to provide continuous enclosure.
- D. Install access doors for access to valves.
- E. Install enclosure continuously from wall to wall.
- F. Terminate enclosures with manufacturer's end caps except where enclosures are indicated to extend to adjoining walls.

3.3 CONNECTIONS

- A. Ground electric finned-tube radiation heaters according to Section 260526 "Grounding and Bonding for Electrical Systems."
- B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

END OF SECTION 238236

SECTION 238239.19 - WALL AND CEILING UNIT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section includes wall and ceiling heaters with propeller fans and electric-resistance heating coils.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For wall and ceiling unit heaters to include in emergency, operation, and maintenance manuals.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Berko; Marley Engineered Products.
 - 2. INDEECO.
 - 3. Markel Products; TPI Corporation.
 - 4. QMark; Marley Engineered Products.

2.2 DESCRIPTION

- A. Assembly including chassis, electric heating coil, fan, motor, and controls. Comply with UL 2021.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 CABINET

- A. Front Panel: Stamped-steel louver , with removable panels fastened with tamperproof fasteners.
- B. Finish: Baked enamel over baked-on primer with manufacturer's standard color selected by Architect, applied to factory-assembled and -tested wall and ceiling heaters before shipping.
- C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Surface-Mounted Cabinet Enclosure: Steel with finish to match cabinet.

2.4 COIL

- A. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and 60-Hz hum, embedded in magnesium oxide refractory and sealed in corrosion-resistant metallic sheath. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware, and limit controls for high-temperature protection. Provide integral circuit breaker for overcurrent protection.

2.5 FAN AND MOTOR

- A. Fan: Aluminum propeller directly connected to motor.
- B. Motor: Permanently lubricated, multispeed. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."

2.6 CONTROLS

- A. Controls: Unit-mounted thermostat. Low-voltage relay with transformer kit.
- B. Electrical Connection: Factory wire motors and controls for a single field connection with disconnect switch.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive wall and ceiling unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for electrical connections to verify actual locations before unit-heater installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install wall and ceiling unit heaters to comply with NFPA 90A.
- B. Install wall and ceiling unit heaters level and plumb.

- C. Install wall-mounted thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.
- D. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
- E. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

END OF SECTION 238239.19