

**SECTION 23 05 13 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT**

**PART 1 GENERAL**

**1.01 SECTION INCLUDES**

- A. General requirements.

**1.02 REFERENCE STANDARDS**

- A. NEMA MG 00001 - Motors and Generators.
- B. NFPA 70 - National Electrical Code.

**1.03 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide wiring diagrams with electrical characteristics and connection requirements.
- C. Test Reports: Indicate test results verifying nominal efficiency and power factor for three phase motors larger than 1/2 horsepower.
- D. Manufacturer's Installation Instructions: Indicate setting, mechanical connections, lubrication, and wiring instructions.
- E. Operation Data: Include instructions for safe operating procedures.
- F. Maintenance Data: Include assembly drawings, bearing data including replacement sizes, and lubrication instructions.

**1.04 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacture of electric motors and their accessories, with minimum three years documented product development, testing, and manufacturing experience.
- B. Comply with NFPA 70.
- C. Provide certificate of compliance from Authority Having Jurisdiction indicating approval of high efficiency motors.
- D. Products Requiring Electrical Connection: Listed and classified by Underwriters Laboratories Inc. as suitable for the purpose specified and indicated.

**1.05 DELIVERY, STORAGE, AND HANDLING**

- A. Protect motors stored on site from weather and moisture by maintaining factory covers and suitable weather-proof covering. For extended outdoor storage, remove motors from equipment and store separately.

**1.06 WARRANTY**

- A. See Section 01 78 00 - Closeout Submittals for additional warranty requirements.

## **PART 2 PRODUCTS**

### **2.01 MANUFACTURERS**

- A. Baldor Electric Company/ABB Group.
- B. Allen-Bradley.
- C. Eaton.
- D. Square D.
- E. General Electric.

### **2.02 GENERAL CREQUIREMENTS**

- A. Motor Requirements:
  - 1. Motors 1/2 HP and Smaller: single phase, 60 Hz unless indicated otherwise on the equipment schedules.
  - 2. Motors Larger than 1/2 Horsepower: three phase, 60 Hz unless indicated otherwise on the equipment schedules.
  - 3. All electronically commutated (EC) motors shall be complete with integral potentiometer, motor power input wire whip, and motor control input wire whip for 0-10 VDC control signal.
  - 4. All motors 1 HP and larger shall meet or exceed requirements of ASHRAE 90.1.
  - 5. All motors 1-1/2 HP and larger shall meet or exceed local utility requirements for high efficiency motors. Mechanical Contractor shall verify current requirements with utility.
  - 6. All motors used on variable frequency drives must be suitable for use with the drive, including but not limited to shaft grounding rings and motor cooling.
- B. Construction:
  - 1. Open drip-proof type except where specifically noted otherwise.
  - 2. Design for continuous operation in 104 degrees F environment.
  - 3. Design for temperature rise in accordance with NEMA MG 00001 limits for insulation class, service factor, and motor enclosure type.
- C. Visible Nameplate: Indicating motor horsepower, voltage, phase, cycles, RPM, full load amps, locked rotor amps, frame size, manufacturer's name and model number, service factor, power factor, efficiency.
- D. Starting Equipment:
  - 1. All starters shall be NEMA standard sizes and all starting equipment shall be of the same manufacturer.
  - 2. All starters, pushbuttons and selector switches shall have NEMA Type 1 enclosures.
- E. Starters

1. All manual starters shall be two pole for single phase fractional horsepower service with lockable on-off switch, hand-off-auto, power-run-fault indication lights, electronic overload protection, control system contacts, auxiliary dry contacts, manual-auto reset selection, fault relay, status relay, and power failure return mode.
  2. All magnetic starters shall be combination type with circuit breaker across the line for three phase service with reset button in cover, pilot light, overload protection for each phase, undervoltage protection, missing phase protection, phase reversal, built-in control circuit transformer with 120 volt operating coils and hand-off-auto selector switch factory mounted in starter flange.
  3. All starters shall be equipped with auxiliary contacts or control relays for equipment control interlocking as required.
- F. Wiring Terminations:
1. Provide terminal lugs to match branch circuit conductor quantities, sizes, and materials indicated. Enclose terminal lugs in terminal box sized to NFPA 70, threaded for conduit.
  2. For fractional horsepower motors where connection is made directly, provide threaded conduit connection in end frame.

### **PART 3 EXECUTION**

#### **3.01 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Install securely on firm foundation. Mount ball bearing motors with shaft in any position.
- C. Check line voltage and phase and ensure agreement with nameplate.

#### **3.02 MECHANICAL CONTRACTOR**

- A. Shall furnish all starting equipment including selector switches, relays, etc. They shall turn all manual and magnetic starters over to the Electrical Contractor with complete instructions and wiring diagrams required for a complete installation. All other control equipment shall be turned over to the Temperature Control subcontractor for installation.
- B. Shall furnish and install all control wiring.
- C. Shall confirm voltage requirements with the Electrical Contractor prior to ordering equipment.

#### **3.03 ELECTRICAL CONTRACTOR**

- A. Will furnish and install all fused and/or circuit breaker disconnect switches, except as indicated otherwise.
- B. Will furnish and install all power wiring from panel board to motors and junction boxes in factory-assembled units.

- C. Will install all starters in cooperation with and under the supervision of the Mechanical Contractor.

**END OF SECTION**

## **SECTION 23 05 23 - GENERAL-DUTY VALVES FOR HVAC PIPING**

### **PART 1 GENERAL**

#### **1.01 SECTION INCLUDES**

- A. Ball valves.
- B. Butterfly valves.
- C. Check valves.

#### **1.02 RELATED REQUIREMENTS**

- A. Section 23 05 53 - Identification for HVAC Piping and Equipment.
- B. Section 23 07 16 - HVAC Equipment Insulation.
- C. Section 23 07 19 - HVAC Piping Insulation.
- D. Section 23 21 13 - Hydronic Piping.
- E. Section 23 22 13 - Steam and Condensate Heating Piping.

#### **1.03 ABBREVIATIONS AND ACRONYMS**

- A. CWP: Cold working pressure.
- B. EPDM: Ethylene propylene copolymer rubber.
- C. NBR: Acrylonitrile-butadiene, Buna-N, or nitrile rubber.
- D. NRS: Nonrising stem.
- E. OS&Y: Outside screw and yoke.
- F. PTFE: Polytetrafluoroethylene.
- G. RS: Rising stem.
- H. TFE: Tetrafluoroethylene.
- I. WOG: Water, oil, and gas.

#### **1.04 REFERENCE STANDARDS**

- A. ASME B1.20.1 - Pipe Threads, General Purpose, Inch.
- B. ASME B16.1 - Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250.
- C. ASME B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard.
- D. ASME B16.10 - Face-to-Face and End-to-End Dimensions of Valves.
- E. ASME B16.18 - Cast Copper Alloy Solder Joint Pressure Fittings.
- F. ASME B16.34 - Valves — Flanged, Threaded, and Welding End.
- G. ASME B31.9 - Building Services Piping.
- H. ASME BPVC-IX - Boiler and Pressure Vessel Code, Section IX - Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators.

- I. ASTM A126 - Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings.
- J. ASTM B62 - Standard Specification for Composition Bronze or Ounce Metal Castings.
- K. AWWA C606 - Grooved and Shouldered Joints.
- L. MSS SP-68 - High Pressure Butterfly Valves with Offset Design.
- M. MSS SP-80 - Bronze Gate, Globe, Angle, and Check Valves.
- N. MSS SP-110 - Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends.
- O. MSS SP-125 - Check Valves: Gray Iron and Ductile Iron, In-Line, Spring-Loaded, Center-Guided.

#### **1.05 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide data on valves including manufacturers catalog information. Submit performance ratings, rough-in details, weights, support requirements, and piping connections.
- C. Warranty: Submit manufacturer warranty and ensure that forms have been completed in Owner's name and registered with manufacturer.
- D. Operation and Maintenance Data: Include manufacturer's descriptive literature, operating instructions, maintenance and repair data, and parts listings.

#### **1.06 QUALITY ASSURANCE**

- A. Manufacturer:
  - 1. Obtain valves for each valve type from single manufacturer.
- B. Welding Materials and Procedures: Comply with ASME BPVC-IX.

#### **1.07 DELIVERY, STORAGE, AND HANDLING**

- A. Prepare valves for shipping as follows:
  - 1. Minimize exposure of operable surfaces by setting plug and ball valves to open position.
  - 2. Protect valve parts exposed to piped medium against rust and corrosion.
  - 3. Protect valve piping connections such as grooves, weld ends, threads, and flange faces.
  - 4. Adjust globe, gate, and angle valves to the closed position to avoid clattering.
  - 5. Secure check valves in either the closed position or open position.
  - 6. Adjust butterfly valves to closed or partially closed position.
- B. Use the following precautions during storage:
  - 1. Maintain valve end protection and protect flanges and specialties from dirt.
    - a. Provide temporary inlet and outlet caps.
    - b. Maintain caps in place until installation.
  - 2. Store valves in shipping containers and maintain in place until installation.
    - a. Store valves indoors in dry environment.

- b. Store valves off the ground in watertight enclosures when indoor storage is not an option.
- C. Exercise the following precautions for handling:
  - 1. Handle large valves with sling, modified to avoid damage to exposed parts.
  - 2. Avoid the use of operating handles or stems as rigging or lifting points.

## **PART 2 PRODUCTS**

### **2.01 APPLICATIONS**

- A. See drawings for specific valve locations.
- B. Listed pipe sizes shown using nominal pipe sizes (NPS) and nominal diameter (DN).
- C. Provide the following valves for the applications if not indicated on drawings:
  - 1. Isolation (Shutoff): Butterfly, Gate, and Ball.
  - 2. Swing Check (Pump Outlet):
    - a. Size 2 inch and Smaller: Bronze with bronze disc.
    - b. Size 2-1/2 inch and Larger: Iron with center-guided with resilient seat.
  - 3. Dead-End: Butterfly, single-flange (lug) type.
- D. Substitutions of valves with higher CWP classes or WSP ratings for same valve types are permitted when specified CWP ratings or WSP classes are not available.
- E. Required Valve End Connections for Non-Wafer Types:
  - 1. Steel Pipe:
    - a. Size 2 inch and Smaller: Threaded ends.
    - b. Size 2-1/2 inch and Larger: Grooved ends.
  - 2. Copper Tube:
    - a. Size 2 inch and Smaller: Threaded ends, except solder-joint valve-ends.
    - b. Size 2-1/2 inch and Larger: Grooved ends.
  - 3. Steam and Steam Condensate Pipe: Grooved ends not acceptable.
- F. Chilled Water Valves:
  - 1. 2 NPS and Smaller, Brass and Bronze Valves:
    - a. Threaded or Solder Ends ends.
    - b. Ball: Full port, two piece, brass trim.
  - 2. Size 2-1/2 inch and Larger, Iron Valves:
    - a. 2-1/2 NPS to 4 NPS: Flanged ends.
    - b. Butterfly: High performance, single flange, Class 150.
- G. Heating Hot Water Valves:
  - 1. Size 2 inch and Smaller, Brass and Bronze Valves:
    - a. Threaded or Solder Ends ends.
    - b. Ball: Full port, two piece, stainless steel trim.

- c. Swing Check: Bronze disc, Class 125.
- 2. Size 2-1/2 inch and Larger, Iron Valves:
  - a. 2-1/2 inch to 4 inch: Threaded ends.
  - b. Butterfly: High performance, single flange, Class 150.
  - c. Center-Guided Check: Compact-wafer, metal seat, Class 125.

## **2.02 GENERAL REQUIREMENTS**

- A. Valve Pressure and Temperature Ratings: No less than rating indicated; as required for system pressures and temperatures.
- B. Valve Sizes: Match upstream piping unless otherwise indicated.
- C. Valve Actuator Types:
  - 1. Gear Actuator: Quarter-turn valves 8 inch and larger.
  - 2. Handwheel: Valves other than quarter-turn types.
  - 3. Hand Lever: Quarter-turn valves 6 inch and smaller.
- D. Valves in Insulated Piping: Provide 2 inch stem extensions and the following features:
  - 1. Ball Valves: Extended operating handle of non-thermal-conductive material, and protective sleeve that allows operation of valve without breaking the vapor seal or disturbing insulation.
  - 2. Butterfly Valves: Extended neck.
- E. Valve-End Connections:
  - 1. Threaded End Valves: ASME B1.20.1.
  - 2. Flanges on Iron Valves: ASME B16.1 for flanges on iron valves.
  - 3. Pipe Flanges and Flanged Fittings 1/2 inch through 24 inch: ASME B16.5.
  - 4. Solder Joint Connections: ASME B16.18.
  - 5. Grooved End Connections: AWWA C606.
- F. General ASME Compliance:
  - 1. Ferrous Valve Dimensions and Design Criteria: ASME B16.10 and ASME B16.34.
  - 2. Building Services Piping Valves: ASME B31.9.
- G. Bronze Valves:
  - 1. Fabricate from dezincification resistant material.
  - 2. Copper alloys containing more than 15 percent zinc are not permitted.
- H. Source Limitations: Obtain each valve type from a single manufacturer.

## **2.03 BRASS, BALL VALVES**

- A. Two Piece, Full Port with Stainless Steel Trim and Female Thread or Solder Connections:
  - 1. Comply with MSS SP-110.
  - 2. SWP Rating: 150 psi.
  - 3. WOG Rating: 600 psi.

4. Vacuum Rating: 28.9 in-Hg.
5. Body: Forged brass.
6. Seats: PTFE.
7. Stem: Stainless Steel.
8. Ball: stainless steel.
9. Manufacturers:
  - a. Apollo Valves: [www.apollovalves.com/#sle](http://www.apollovalves.com/#sle).
  - b. FNW; 410A: [www.fnw.com/#sle](http://www.fnw.com/#sle).
  - c. Substitutions: See Section 01 60 00 - Product Requirements.

#### **2.04 BRONZE, BALL VALVES**

- A. General:
  1. Fabricate from dezincification resistant material.
  2. Copper alloys containing more than 15 percent zinc are not permitted.
- B. Two Piece, Full Port with Stainless Steel Trim:
  1. Comply with MSS SP-110.
  2. WSP Rating: 150 psi.
  3. WOG Rating: 400 psi.
  4. Body: Forged bronze or dezincified-brass alloy.
  5. End Connections: Pipe thread or solder.
  6. Seats: PTFE.
  7. Stem: Stainless steel.
  8. Ball: Stainless steel, vented.
  9. Manufacturers:
    - a. Apollo Valves: [www.apollovalves.com/#sle](http://www.apollovalves.com/#sle).
    - b. FNW; X450: [www.fnw.com/#sle](http://www.fnw.com/#sle).
    - c. Substitutions: See Section 01 60 00 - Product Requirements.

#### **2.05 HIGH-PERFORMANCE, SINGLE FLANGE BUTTERFLY VALVES**

- A. Lug type; Bidirectional dead end service without downstream flange:
  1. Comply with MSS SP-68.
  2. Class 150: CWP Rating: 285 psi at 100 degrees F.
  3. Body: Provide carbon steel, cast iron, ductile Iron, or stainless steel.
  4. Seat: Metal or reinforced PTFE.
  5. Offset stem: Stainless steel.
  6. Disc: Carbon steel.
  7. Operator: Lockable handle over direct-mount actuator base.

## **2.06 BRONZE, SWING CHECK VALVES**

- A. Class 125:
  - 1. Pressure and Temperature Rating: MSS SP-80, Type 3.
  - 2. Design: Y-pattern, horizontal or vertical flow.
  - 3. WSP Rating: 200 psi.
  - 4. Body: Bronze, ASTM B62.
  - 5. End Connections: Threaded or soldered.
  - 6. Disc: Bronze.

## **2.07 IRON, CENTER-GUIDED CHECK VALVES**

- A. Class 125, Compact-Wafer:
  - 1. Comply with MSS SP-125.
  - 2. Sizes 2-1/2 to 12 inch: CWP Rating; 200 psi.
  - 3. Body Material: ASTM A126, gray iron.
  - 4. Resilient Seat: EPDM or NBR.

## **PART 3 EXECUTION**

### **3.01 EXAMINATION**

- A. Discard all packing materials and verify that valve interior, including threads and flanges, are completely clean without signs of damage or degradation that could result in leakage.
- B. Verify valve parts to be fully operational in all positions from closed to fully open.
- C. Confirm gasket material to be suitable for the service, to be of correct size, and without defects that could compromise effectiveness.
- D. Should valve is determined to be defective, replace with new valve.

### **3.02 INSTALLATION**

- A. Provide unions or flanges with valves to facilitate equipment removal and maintenance while maintaining system operation and full accessibility for servicing.
- B. Provide separate valve support as required and locate valve with stem at or above center of piping, maintaining unimpeded stem movement.

## **END OF SECTION**

**SECTION 23 05 29 - HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT**

**PART 1 GENERAL**

**1.01 REFERENCE STANDARDS**

- A. MFMA-4 - Metal Framing Standards Publication.
- B. MSS SP-58 - Pipe Hangers and Supports - Materials, Design, Manufacture, Selection, Application, and Installation.
- C. UL 723 - Standard for Test for Surface Burning Characteristics of Building Materials.

**1.02 ADMINISTRATIVE REQUIREMENTS**

- A. Coordination:
  - 1. Coordinate sizes and arrangement of supports and bases with the actual equipment and components to be installed.
  - 2. Coordinate the work with other trades to provide additional framing and materials required for installation.
  - 3. Coordinate compatibility of support and attachment components with mounting surfaces at the installed locations.
  - 4. Coordinate the arrangement of supports with ductwork, piping, equipment and other potential conflicts installed under other sections or by others.
  - 5. Notify Architect of any conflicts with or deviations from Contract Documents. Obtain direction before proceeding with work.
- B. Sequencing:
  - 1. Do not install products on or provide attachment to concrete surfaces until concrete has fully cured in accordance with Section 03 30 00.

**1.03 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide manufacturer's standard catalog pages and data sheets.
- C. Shop Drawings: Include details for fabricated hangers and supports where materials or methods other than those indicated are proposed for substitution.
- D. Manufacturer's Instructions: Indicate application conditions and limitations of use stipulated by product testing agency. Include instructions for storage, handling, protection, examination, preparation, and installation of product.

**1.04 QUALITY ASSURANCE**

- A. Comply with applicable building code.
- B. Installer Qualifications for Field-Welding: As specified in Section 05 50 00.

**1.05 DELIVERY, STORAGE, AND HANDLING**

- A. Receive, inspect, handle, and store products in accordance with manufacturer's instructions.

## **PART 2 PRODUCTS**

### **2.01 SUPPORT AND ATTACHMENT COMPONENTS**

- A. General Requirements:
  - 1. Provide all required hangers, supports, anchors, fasteners, fittings, accessories, and hardware as necessary for the complete installation of work.
  - 2. Provide products listed, classified, and labeled as suitable for the purpose intended, where applicable.
  - 3. Where support and attachment component types and sizes are not indicated, select in accordance with manufacturer's application criteria as required for the load to be supported. Include consideration for vibration, equipment operation, and shock loads where applicable.
  - 4. Do not use wire, chain, perforated pipe strap, or wood for permanent supports unless specifically indicated or permitted.
  - 5. Steel Components: Use corrosion resistant materials suitable for the environment where installed.
- B. Manufacturers:
  - 1. B-Line, a brand of Eaton Corporation
  - 2. Gripple, Inc
  - 3. Unistrut, a brand of Atkore International Inc
- C. Hanger Rods:
  - 1. Threaded zinc-plated steel unless otherwise indicated.
  - 2. Minimum Size, Unless Otherwise Indicated or Required:
    - a. Equipment Supports: 1/2 inch diameter.
    - b. Piping up to 1 inch: 1/4 inch diameter.
    - c. Piping larger than 1 inch: 3/8 inch diameter.
    - d. Trapeze Support for Multiple Pipes: 3/8 inch diameter.
- D. Beam Clamps:
  - 1. Forged steel concentric loaded type with tie rod to lock clamp in place for all piping 5" through 8". C type clamps may be used for piping smaller than 5".
- E. Riser Clamps:
  - 1. Furnish Grinnell Fig. 261 clamps to support vertical piping where required.
  - 2. For insulated pipe runs, provide two bolt-type clamps designed for installation under insulation.
- F. Pipe Hangers:
  - 1. Manufacturers:
    - a. B-Line, a brand of Eaton Corporation

- b. Gripple, Inc
  - c. Unistrut, a brand of Atkore International Inc
- 2. Furnish Grinnell Fig. 260 clevis type pipe hangers for all piping unless otherwise indicated.
- 3. Furnish Grinnell copper plated Fig CT-65 light duty adjustable wrought clevis copper tubing hangers for uninsulated copper tubing.
- 4. Furnish Grinnell Fig. 171 single pipe roll for all individual run hot piping 8" diameter and larger. For hot piping 1-1/2" diameter and larger and grouped on trapeze hangers or brackets, use Grinnell Fig. 274 adjustable pipe rolls. Note: Pipe rolls shall not be used closer than 20 ft. to a horizontal elbow.
- G. Pipe Saddles and Shields for Insulated Piping:
  - 1. Furnish Grinnell pipe covering protection saddles at all hanger locations on insulated hot piping 1-1/2" and larger.
  - 2. Furnish Grinnell Fig. 167 protection shields at all hanger locations on insulated piping smaller than 1-1/2".
  - 3. Furnish Grinnell Fig. 167 protection shields at all hanger locations on piping insulated with vapor barrier pipe covering.

### **PART 3 EXECUTION**

#### **3.01 EXAMINATION**

- A. Verify that field measurements are as indicated.
- B. Verify that mounting surfaces are ready to receive support and attachment components.
- C. Verify that conditions are satisfactory for installation prior to starting work.

#### **3.02 INSTALLATION**

- A. Install products in accordance with manufacturer's instructions.
- B. Support all piping neatly and in an approved manner to allow for expansion, contraction and vibration. Piping shall be supported not more than 10 ft. between hangers and closer where required to prevent sagging or where required by local code, ordinance or the International Fuel Gas Code.
- C. On hot piping, smaller than 1-1/2", the hanger may be secured directly to the pipe and the pipe insulation surround the hanger.
- D. On hot piping, 1-1/2" and larger, the covering protection saddles specified above shall rest on the pipe insulation and the hanger shall surround the outside of the pipe insulation and protection saddles specified.
- E. On all cold piping with vapor barrier insulation, the covering protection shields specified above shall rest on the pipe insulation and the hanger shall surround the outside of the pipe insulation and sheet metal protection shields specified.

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- F. Provide independent support from building structure. Do not provide support from piping, ductwork, conduit, or other systems.
- G. Unless specifically indicated or approved by the Engineer, do not provide support from suspended ceiling support system or ceiling grid.
- H. Unless specifically indicated or approved by the Engineer, do not provide support from roof deck.
- I. Do not penetrate or otherwise notch or cut structural members without approval of Structural Engineer.
- J. Remove all new or existing temporary supports.

**END OF SECTION**

**SECTION 23 05 53 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT**

**PART 1 GENERAL**

**1.01 SECTION INCLUDES**

- A. Nameplates.
- B. Tags.
- C. Adhesive-backed duct markers.
- D. Pipe markers.

**1.02 REFERENCE STANDARDS**

- A. ASME A13.1 - Scheme for the Identification of Piping Systems.

**1.03 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide manufacturers catalog literature for each product required.
- C. Project Record Documents: Record actual locations of tagged valves.

**PART 2 PRODUCTS**

**2.01 IDENTIFICATION APPLICATIONS**

- A. Air Handling Equipment: Nameplates.
- B. Air Terminal Units: Nameplates.
- C. Control Panels: Nameplates.
- D. Ductwork: Adhesive-Backed Duct Markers.
- E. Major Control Components: Nameplates.
- F. Piping: Pipe markers.
- G. Pumps: Nameplates.
- H. Valves: Tags.
- I. Water Treatment Devices: Nameplates.

**2.02 NAMEPLATES**

- A. Plastic: Comply with ASTM D709.
  - 1. Letter Color: White.
  - 2. Letter Height: 1/4 inch.
  - 3. Background Color: Black.

**2.03 TAGS**

- A. Plastic Tags: Engraved three-layer.
  - 1. Letter Color: White
  - 2. Letter Height: 1/4 inch (Minimum)
  - 3. Background Color: Black.

4. Tag size: 1-1/2 inch diameter (Minimum)

#### **2.04 ADHESIVE-BACKED DUCT MARKERS**

- A. Material: High gloss acrylic adhesive-backed vinyl film 0.0032 inch; printed with UV and chemical resistant inks.
- B. Style: Individual Label.
- C. Color: Green/White.

#### **2.05 PIPE MARKERS**

- A. Color: Comply with ASME A13.1.
- B. Plastic Pipe Markers: Flexible, vinyl film tape with pressure-sensitive adhesive backing and printed markings; minimum information indicating flow direction arrow and identification of fluid being conveyed.

### **PART 3 EXECUTION**

#### **3.01 PREPARATION**

- A. Degrease and clean surfaces to receive adhesive for identification materials.

#### **3.02 INSTALLATION**

- A. Install nameplates with adhesive. Apply with sufficient adhesive to ensure permanent adhesion and seal with clear lacquer.
- B. Install tags with corrosion resistant chain.
- C. Install plastic pipe markers in accordance with manufacturer's instructions.
  1. Identify service, flow direction, and pressure.
  2. Install in clear view and align with axis of piping.
  3. Locate identification not to exceed 20 feet on straight runs including risers and drops.

### **END OF SECTION**

**SECTION 23 05 93 - TESTING, ADJUSTING, AND BALANCING FOR HVAC**

**PART 1 GENERAL**

**1.01 REFERENCE STANDARDS**

- A. AABC (NSTSB) - AABC National Standards for Total System Balance, 7th Edition.
- B. ASHRAE Std 111 - Measurement, Testing, Adjusting, and Balancing of Building HVAC Systems.
- C. SMACNA (TAB) - HVAC Systems Testing, Adjusting and Balancing.

**1.02 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements, for submittal procedures.
- B. Installer Qualifications: Submit name of adjusting and balancing agency and TAB supervisor for approval within 30 days after award of Contract.
- C. Final Report: Indicate deficiencies in systems that would prevent proper testing, adjusting, and balancing of systems and equipment to achieve specified performance.
  - 1. Submit draft copies of report for review prior to final acceptance of Project. Provide final copies for Architect and for inclusion in operating and maintenance manuals.
  - 2. Include actual instrument list, with manufacturer name, serial number, and date of calibration.
  - 3. Form of Test Reports: Where the TAB standard being followed recommends a report format use that; otherwise, follow ASHRAE Std 111.
  - 4. Units of Measure: Report data in I-P (inch-pound) units only.
  - 5. Include the following on the title page of each report:
    - a. Name of Testing, Adjusting, and Balancing Agency.
    - b. Address of Testing, Adjusting, and Balancing Agency.
    - c. Telephone number of Testing, Adjusting, and Balancing Agency.
    - d. Project name.
    - e. Project location.
    - f. Project Architect.
    - g. Project Engineer.
    - h. Project Contractor.
    - i. Report date.

**PART 2 PRODUCTS - NOT USED**

**PART 3 EXECUTION**

**3.01 GENERAL REQUIREMENTS**

- A. Perform total system balance in accordance with one of the following:
  - 1. AABC (NSTSB), AABC National Standards for Total System Balance.

2. NEBB, National Environmental Balancing Bureau.
3. SMACNA (TAB).
- B. Begin work after completion of systems to be tested, adjusted, or balanced and complete work prior to Substantial Completion of the project.
- C. Where HVAC systems and/or components interface with life safety systems, including fire and smoke detection, alarm, and control, coordinate scheduling and testing and inspection procedures with the authorities having jurisdiction.
- D. TAB Agency Qualifications:
  1. Company specializing in the testing, adjusting, and balancing of systems specified in this section.
  2. Having minimum of three years documented experience.
  3. Certified by one of the following:
    - a. AABC, Associated Air Balance Council: [www.aabc.com/#sle](http://www.aabc.com/#sle); upon completion submit AABC National Performance Guaranty.
    - b. NEBB, National Environmental Balancing Bureau: [www.nebb.org/#sle](http://www.nebb.org/#sle).
    - c. TABB, The Testing, Adjusting, and Balancing Bureau of National Energy Management Institute: [www.tabbcertified.org/#sle](http://www.tabbcertified.org/#sle).
- E. TAB Supervisor and Technician Qualifications: Certified by same organization as TAB agency.

### **3.02 EXAMINATION**

- A. Verify that systems are complete and operable before commencing work. Ensure the following conditions:
  1. Systems are started and operating in a safe and normal condition.
  2. Temperature control systems are installed complete and operable.
  3. Proper thermal overload protection is in place for electrical equipment.
  4. Final filters are clean and in place. If required, install temporary media in addition to final filters.
  5. Duct systems are clean of debris.
  6. Fans are rotating correctly.
  7. Fire and volume dampers are in place and open.
  8. Air coil fins are cleaned and combed.
  9. Access doors are closed and duct end caps are in place.
  10. Air outlets are installed and connected.
  11. Duct system leakage is minimized.
  12. Hydronic systems are flushed, filled, and vented.
  13. Pumps are rotating correctly.
  14. Proper strainer baskets are clean and in place.
  15. Service and balance valves are open.

- B. Submit field reports. Report defects and deficiencies that will or could prevent proper system balance.
- C. Beginning of work means acceptance of existing conditions.

### **3.03 PREPARATION**

- A. Provide instruments required for testing, adjusting, and balancing operations. Make instruments available to Architect to facilitate spot checks during testing.
- B. Provide additional balancing devices as required.

### **3.04 ADJUSTMENT TOLERANCES**

- A. Air Handling Systems: Adjust to within plus or minus 5 percent of design for supply systems and plus or minus 10 percent of design for return and exhaust systems.
- B. Air Outlets and Inlets: Adjust total to within plus 10 percent and minus 5 percent of design to space. Adjust outlets and inlets in space to within plus or minus 10 percent of design.
- C. Hydronic Systems: Adjust to within plus or minus 10 percent of design.

### **3.05 RECORDING AND ADJUSTING**

- A. Field Logs: Maintain written logs including:
  - 1. Running log of events and issues.
  - 2. Discrepancies, deficient or uncompleted work by others.
  - 3. Contract interpretation requests.
  - 4. Lists of completed tests.
- B. Ensure recorded data represents actual measured or observed conditions.
- C. Permanently mark settings of valves, dampers, and other adjustment devices allowing settings to be restored. Set and lock memory stops.
- D. After adjustment, take measurements to verify balance has not been disrupted or that such disruption has been rectified.
- E. Leave systems in proper working order, replacing belt guards, closing access doors, closing doors to electrical switch boxes, and restoring thermostats to specified settings.

### **3.06 AIR SYSTEM PROCEDURE**

- A. Adjust air handling and distribution systems to provide required or design supply, return, and exhaust air quantities at site altitude.
- B. Make air quantity measurements in ducts by Pitot tube traverse of entire cross sectional area of duct.
- C. Measure air quantities at air inlets and outlets.
- D. Adjust distribution system to obtain uniform space temperatures free from objectionable drafts and noise.

- E. Use volume control devices to regulate air quantities only to extend that adjustments do not create objectionable air motion or sound levels. Effect volume control by duct internal devices such as dampers and splitters.
- F. Vary total system air quantities by adjustment of fan speeds. Provide drive changes required. Vary branch air quantities by damper regulation.
- G. Provide system schematic with required and actual air quantities recorded at each outlet or inlet.
- H. Measure static air pressure conditions on air supply units, including filter and coil pressure drops, and total pressure across the fan. Make allowances for 50 percent loading of filters.
- I. Adjust outside air automatic dampers, outside air, return air, and exhaust dampers for design conditions.
- J. Measure temperature conditions across outside air, return air, and exhaust dampers to check leakage.
- K. Where modulating dampers are provided, take measurements and balance at extreme conditions. Balance variable volume systems at maximum air flow rate, full cooling, and at minimum air flow rate, full heating.
- L. Measure building static pressure and adjust supply, return, and exhaust air systems to provide required relationship between each to maintain approximately 0.05 inches positive static pressure near the building entries.

### **3.07 WATER SYSTEM PROCEDURE**

- A. Adjust water systems to provide required or design quantities.
- B. Use calibrated Venturi tubes, orifices, or other metered fittings and pressure gauges to determine flow rates for system balance. Where flow metering devices are not installed, base flow balance on temperature difference across various heat transfer elements in the system.
- C. Adjust systems to provide specified pressure drops and flows through heat transfer elements prior to thermal testing. Perform balancing by measurement of temperature differential in conjunction with air balancing.
- D. Effect system balance with automatic control valves fully open to heat transfer elements.
- E. Effect adjustment of water distribution systems by means of balancing cocks, valves, and fittings. Do not use service or shut-off valves for balancing unless indexed for balance point.
- F. Where available pump capacity is less than total flow requirements or individual system parts, full flow in one part may be simulated by temporary restriction of flow to other parts.

### **3.08 SCOPE**

- A. Test, adjust, and balance the following (New and Existing):
  - 1. HVAC Pumps.
  - 2. Packaged Roof Top Heating/Cooling Units.

3. Air Coils.
4. Terminal Heat Transfer Units.
5. Air Handling Units.
6. Fans.
7. Air Terminal Units.
8. Air Inlets and Outlets.

### **3.09 MINIMUM DATA TO BE REPORTED**

- A. Electric Motors:
  1. Manufacturer.
  2. Model/Frame.
  3. HP/BHP.
  4. Phase, voltage, amperage; nameplate, actual, no load.
  5. RPM.
  6. Service factor.
  7. Starter size, rating, heater elements.
  8. Sheave Make/Size/Bore.
- B. V-Belt Drives:
  1. Identification/location.
  2. Required driven RPM.
  3. Driven sheave, diameter and RPM.
  4. Belt, size and quantity.
  5. Motor sheave diameter and RPM.
- C. Pumps:
  1. Identification/number.
  2. Manufacturer.
  3. Size/model.
  4. Impeller.
  5. Service.
  6. Design flow rate, pressure drop, BHP.
  7. Actual flow rate, pressure drop, BHP.
  8. Discharge pressure.
  9. Suction pressure.
  10. Total operating head pressure.
  11. Shut off, discharge and suction pressures.
  12. Shut off, total head pressure.
- D. Existing Heating Coils:
  1. Identification/number.

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2. Location.
3. Service.
4. Manufacturer.
5. Air flow, design and actual.
6. Water flow, design and actual.
7. Water pressure drop, design and actual.
8. Entering water temperature, design and actual.
9. Leaving water temperature, design and actual.
10. Entering air temperature, design and actual.
11. Leaving air temperature, design and actual.
12. Air pressure drop, design and actual.

E. Air Moving Equipment:

1. Location.
2. Manufacturer.
3. Model number.
4. Serial number.
5. Arrangement/Class/Discharge.
6. Air flow, specified and actual.
7. Return air flow, specified and actual.
8. Outside air flow, specified and actual.
9. Total static pressure (total external), specified and actual.
10. Inlet pressure.
11. Discharge pressure.
12. Water pressure drop, design and actual. Entering water temperature, design and actual. Leaving water temperature, design and actual.
13. Entering water temperature, design and actual. Leaving water temperature, design and actual.
14. Sheave Make/Size/Bore.
15. Number of Belts/Make/Size.
16. Leaving water temperature, design and actual.
17. Fan RPM.
18. Water pressure drop, design and actual. Entering water temperature, design and actual. Leaving water temperature, design and actual.
19. Entering water temperature, design and actual. Leaving water temperature, design and actual.
20. Leaving water temperature, design and actual.

F. Exhaust and supply Fans:

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1. Location.
2. Manufacturer.
3. Model number.
4. Serial number.
5. Air flow, specified and actual.
6. Total static pressure (total external), specified and actual.
7. Inlet pressure.
8. Discharge pressure.
9. Sheave Make/Size/Bore.
10. Number of Belts/Make/Size.
11. Fan RPM.

G. Air Monitoring Stations:

1. Identification/location.
2. System.
3. Size.
4. Area.
5. Design velocity.
6. Design air flow.
7. Test velocity.
8. Test air flow.

H. Terminal Unit Data:

1. Manufacturer.
2. Type, constant, variable, single, dual duct.
3. Identification/number.
4. Location.
5. Model number.
6. Size.
7. Minimum static pressure.
8. Minimum design air flow.
9. Maximum design air flow.
10. Maximum actual air flow.
11. Inlet static pressure.
12. Water pressure drop, design and actual. Entering water temperature, design and actual. Leaving water temperature, design and actual.
13. Entering water temperature, design and actual. Leaving water temperature, design and actual.

14. Leaving water temperature, design and actual.

**END OF SECTION**

**SECTION 23 07 13 - DUCT INSULATION**

**PART 1 GENERAL**

**1.01 SECTION INCLUDES**

- A. Duct insulation.
- B. Duct liner.

**1.02 REFERENCE STANDARDS**

- A. ASTM C518 - Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus.
- B. ASTM C553 - Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications.
- C. ASTM C612 - Standard Specification for Mineral Fiber Block and Board Thermal Insulation.
- D. ASTM C916 - Standard Specification for Adhesives for Duct Thermal Insulation.
- E. ASTM C1071 - Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material).
- F. ASTM E84 - Standard Test Method for Surface Burning Characteristics of Building Materials.
- G. ASTM E96/E96M - Standard Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials.
- H. ASTM G21 - Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi.
- I. SMACNA (DCS) - HVAC Duct Construction Standards Metal and Flexible.
- J. UL 723 - Standard for Test for Surface Burning Characteristics of Building Materials.

**1.03 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide product description, thermal characteristics, list of materials and thickness for each service, and locations.
- C. Manufacturer's Instructions: Indicate installation procedures necessary to ensure acceptable workmanship and that installation standards will be achieved.

**1.04 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacturing products of the type specified in this section with not less than three years of documented experience.
- B. Applicator Qualifications: Company specializing in performing the type of work specified in this section, with minimum 3 years of experience and approved by manufacturer.

**1.05 DELIVERY, STORAGE, AND HANDLING**

- A. Accept materials on site in original factory packaging, labelled with manufacturer's identification, including product density and thickness.

- B. Protect insulation from weather and construction traffic, dirt, water, chemical, and mechanical damage, by storing in original wrapping.

#### **1.06 FIELD CONDITIONS**

- A. Maintain ambient temperatures and conditions required by manufacturers of adhesives, mastics, and insulation cements.
- B. Maintain temperature during and after installation for minimum period of 24 hours.

### **PART 2 PRODUCTS**

#### **2.01 REGULATORY REQUIREMENTS**

- A. Surface Burning Characteristics: Flame spread index/Smoke developed index of 25/50, maximum, when tested in accordance with ASTM E84 or UL 723.

#### **2.02 GLASS FIBER, FLEXIBLE**

- A. Manufacturer:
  - 1. CertainTeed Corporation
  - 2. Johns Manville
  - 3. Knauf Insulation
- B. Insulation: ASTM C553; flexible, noncombustible blanket.
  - 1. K value: 0.36 at 75 degrees F, when tested in accordance with ASTM C518.
  - 2. Maximum Service Temperature: 1,200 degrees F.
  - 3. Maximum Water Vapor Absorption: 5.0 percent by weight.
- C. Vapor Barrier Jacket:
  - 1. Kraft paper with glass fiber yarn and bonded to aluminized film.
  - 2. Moisture Vapor Permeability: 0.02 perm inch, when tested in accordance with ASTM E96/E96M.
  - 3. Secure with pressure-sensitive tape.
- D. Vapor Barrier Tape:
  - 1. Kraft paper reinforced with glass fiber yarn and bonded to aluminized film, with pressure-sensitive rubber-based adhesive.
- E. The entire assembly shall provide a minimum "installed R value" of 6 for all indoor ductwork.
- F. The entire assembly shall provide a minimum "installed R value" of 10 for all outdoor ductwork.

#### **2.03 GLASS FIBER, RIGID**

- A. Manufacturer:
  - 1. CertainTeed Corporation
  - 2. Johns Manville
  - 3. Knauf Insulation
- B. Insulation: ASTM C612; rigid, noncombustible blanket.

1. K Value: 0.24 at 75 degrees F, when tested in accordance with ASTM C518.
  2. Maximum Service Temperature: 450 degrees F.
  3. Maximum Water Vapor Absorption: 5.0 percent.
  4. Maximum Density: 8.0 pcf.
- C. Vapor Barrier Jacket:
1. Kraft paper with glass fiber yarn and bonded to aluminized film.
  2. Moisture Vapor Permeability: 0.02 perm inch, when tested in accordance with ASTM E96/E96M.
  3. Secure with pressure-sensitive tape.
- D. Vapor Barrier Tape:
1. Kraft paper reinforced with glass fiber yarn and bonded to aluminized film, with pressure-sensitive rubber-based adhesive.
- E. The entire assembly shall provide a minimum "installed R value" of 6 for all indoor ductwork.
- F. The entire assembly shall provide a minimum "installed R value" of 10 for all outdoor ductwork.

## **2.04 DUCT LINER**

- A. Manufacturers:
1. CertainTeed Corporation
  2. Johns Manville
  3. Knauf Insulation
- B. Glass Fiber Insulation: Non-corrosive, incombustible glass fiber complying with ASTM C1071; flexible blanket, rigid board, and preformed round liner board; impregnated surface and edges coated with poly vinyl acetate polymer, acrylic polymer, or black composite.
1. Fungal Resistance: No growth when tested according to ASTM G21.
  2. Apparent Thermal Conductivity: Maximum of 0.31 at 75 degrees F.
  3. Service Temperature: Up to 250 degrees F.
  4. Rated Velocity on Coated Air Side for Air Erosion: 5,000 fpm, minimum.
  5. Minimum size:
    - a. 1 inch Thickness: Return, transfer and exhaust ductwork.
    - b. 2 inch Thickness: Supply ductwork.
- C. Adhesive: Waterproof, fire-retardant type, ASTM C916.
- D. Liner Fasteners: Galvanized steel, self-adhesive pad with integral head.

## **PART 3 EXECUTION**

### **3.01 EXAMINATION**

- A. Test ductwork for design pressure prior to applying insulation materials.
- B. Verify that surfaces are clean, foreign material removed, and dry.

### **3.02 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Insulated Ducts Conveying Air Below Ambient Temperature:
  - 1. Provide insulation with vapor barrier jackets.
  - 2. Finish with tape and vapor barrier jacket.
  - 3. Continue insulation through walls, sleeves, hangers, and other duct penetrations.
  - 4. Insulate entire system, including fittings, joints, flanges, fire dampers, flexible connections, and expansion joints.
- C. Insulated Ducts Conveying Air Above Ambient Temperature:
  - 1. Provide with or without standard vapor barrier jacket.
  - 2. Insulate fittings and joints. Where service access is required, bevel and seal ends of insulation.
- D. Duct Liner Application:
  - 1. Secure insulation with mechanical liner fasteners. Refer to SMACNA (DCS) for spacing.
  - 2. Seal and smooth joints. Seal and coat transverse joints.
  - 3. Seal liner surface penetrations with adhesive.
  - 4. Duct dimensions indicated are net inside dimensions required for airflow. Increase duct size to allow for insulation thickness.

### **3.03 SCHEDULES**

- A. Exhaust Ducts: 1" glass fiber, rigid from automatic air damper to roof or wall termination (except where ductwork is lined).
- B. Outside Air Intake Ducts: 2" glass fiber, rigid.
- C. Supply Ducts: 2" glass fiber, flexible; 2" duct liner where indicated.
- D. Supply Ducts in Mechanical Rooms: 2" glass fiber, rigid.
- E. Return and Exhaust Ducts: 1" duct liner where indicated.
- F. Return and Exhaust Ducts in Mechanical Rooms: 1" glass fiber, rigid.

### **END OF SECTION**

## **SECTION 23 07 19 - HVAC PIPING INSULATION**

### **PART 1 GENERAL**

#### **1.01 SECTION INCLUDES**

- A. Piping insulation.
- B. Flexible removable and reusable blanket insulation.

#### **1.02 RELATED REQUIREMENTS**

- A. Section 07 84 00 - Firestopping.

#### **1.03 REFERENCE STANDARDS**

- A. ASTM C795 - Standard Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel.
- B. ASTM E84 - Standard Test Method for Surface Burning Characteristics of Building Materials.
- C. ASTM E96/E96M - Standard Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials.
- D. UL 723 - Standard for Test for Surface Burning Characteristics of Building Materials.

#### **1.04 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide product description, thermal characteristics, list of materials and thickness for each service, and locations.

#### **1.05 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacturing the Products specified in this section with not less than three years of documented experience.

#### **1.06 DELIVERY, STORAGE, AND HANDLING**

- A. Accept materials on site, labeled with manufacturer's identification, product density, and thickness.

#### **1.07 FIELD CONDITIONS**

- A. Maintain ambient conditions required by manufacturers of each product.
- B. Maintain temperature before, during, and after installation for minimum of 24 hours.

### **PART 2 PRODUCTS**

#### **2.01 REGULATORY REQUIREMENTS**

- A. Surface Burning Characteristics: Flame spread index/Smoke developed index of 25/50, maximum, when tested in accordance with ASTM E84 or UL 723.

#### **2.02 GLASS FIBER**

- A. Manufacturers:

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1. CertainTeed Corporation
2. Johns Manville Corporation
3. Knauf Insulation
4. Owens Corning Corporation

B. Hot Piping:

1. Complete with flame retardant kraft reinforced foil all service white jacket. Jacket shall have a factory applied double pressure sensitive adhesive to adhesive closure flap. Circumferential end joints shall be sealed with self-sealing 3" wide kraft reinforced foil white butt strips.
2. All valve bodies, flanges, clamp type pipe couplings and fittings shall be wrapped with fiberglass blanket, or segments of pipe insulation securely tied in place to a thickness slightly greater than the adjoining insulation. Wrap Manville "Zerotape" over the insulation and finish with an open weave glass cloth imbedded in two coats of Benjamin Foster No. 30-36 or Childers CP-50 fire resistive white sealer.
3. Premolded one piece 25/50 rated PVC insulated fitting covers may be used in lieu of insulating cement and glass cloth at valve bodies, flanges, clamp type couplings and fittings. Factory pre-cut fiberglass insulation shall be applied to the fitting with the insulation tucked into the throat of the fitting and the edges of the adjacent pipe covering. The PVC cover shall be applied and secured by stapling and applying pressure sensitive tape over the staples and at the circumferential edges.
4. Vertical soft copper tubing concealed in building construction shall be covered with Armaflex AP, Aeroflex or Rubatex flexible, plenum rated, antimicrobial, closed cell elastomeric foam pipe insulation. All joints and seams are to be sealed with Armaflex 520 BLV low VOC adhesive or equal.

C. Cold Piping:

1. Complete with flame retardant kraft reinforced foil all service white vapor barrier jacket. Jacket shall have a factory applied double pressure sensitive adhesive to adhesive closure flap. Circumferential end joints shall be sealed with 3" wide self-sealing kraft reinforced foil vapor barrier white butt strips.
2. All valve bodies, flanges, clamp type pipe couplings and fittings shall be wrapped with fiberglass blanket, or segments of pipe insulation securely tied in place to a thickness slightly greater than the adjoining insulation. Wrap Manville "Zerotape" over the insulation and finish with an open weave glass cloth imbedded in two coats of Benjamin Foster No. 30-36 or Childers CP-50 fire resistive white sealer.

3. Premolded one piece 25/50 rated PVC insulated fitting covers may be used in lieu of insulating cement and glass cloth at valve bodies, flanges, clamp type couplings and fittings. Factory pre-cut fiberglass insulation shall be applied to the fitting with the insulation tucked into the throat of the fitting and the edges of the adjacent pipe covering. The PVC cover shall be applied and secured by stapling and applying vapor barrier pressure sensitive tape over the staples and at the circumferential edges. The tape shall have an overlap on itself of at least 2". All seam edges of the cover shall be sealed with vapor barrier adhesive.
4. At each pipe hanger location, provide half-round, 6" long, hanger block at the bottom half of the piping in place of the pipe insulation. The hanger blocks shall be wood or asbestos free calcium silicate pipe insulation of the same thickness as the adjoining pipe insulation. The vapor barrier jacket shall be continuous through the hanger location and a 16 gauge 12" long galvanized sheet steel saddle shall be wrapped around the pipe insulation between the jacket and the hanger.
5. Entire installation shall be vapor proof. Any breaks, rips, tears or omission of vapor barrier shall be repaired.

D. Hot Equipment:

1. One and one half inch (1-1/2") thickness 3 lbs. per cu. ft. density fiberglass semi-rigid board insulation with factory applied aluminum foil reinforced kraft facing. Insulation shall be adhered to the surfaces with fire resistive adhesive (100% coverage). All edges and joints shall be sealed with 3" wide reinforced aluminum foil pressure sensitive joint sealing tape. All flaps shall be pasted and sealed with Benjamin-Foster No. 85-20 or Childers CP-82 fire resistive white adhesive. Completely cover the insulation with a heavy coat of Benjamin-Foster 30-36 Sealfas or Childers CP-50. Imbed an open weave glass cloth and while still wet apply a finish coat of Benjamin-Foster 30-36 or Childers CP-50 fire resistive white sealer.
2. Type of Equipment:
  - a. Air and Dirt Separators.

## 2.03 ACCESSORIES

A. General Requirements:

1. Furnish compatible materials which do not contribute to corrosion, soften, or otherwise attack surfaces to which applied, in either the wet or dry state.
2. Comply with ASTM C795 requirements for materials to be used on stainless steel surfaces.
3. Supply materials that are asbestos free.

### **PART 3 EXECUTION**

#### **3.01 EXAMINATION**

- A. Test piping for design pressure, liquid tightness, and continuity prior to applying insulation materials.
- B. Verify that surfaces are clean and dry, with foreign material removed.

#### **3.02 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Exposed Piping: Locate insulation and cover seams in least visible locations.
- C. Insulated Pipes Conveying Fluids Below Ambient Temperature:
  - 1. Insulate entire system, including fittings, valves, unions, flanges, strainers, flexible connections, pump bodies, and expansion joints.
- D. Glass Fiber Insulated Pipes Conveying Fluids Below Ambient Temperature:
  - 1. Provide vapor barrier jackets, factory-applied or field-applied; secure with self-sealing longitudinal laps and butt strips with pressure-sensitive adhesive. Secure with outward clinch expanding staples and vapor barrier mastic.
  - 2. Insulate fittings, joints, and valves with molded insulation of like material and thickness as adjacent pipe. Finish with glass cloth and vapor barrier adhesive or PVC fitting covers.
- E. Glass Fiber Insulated Pipes Conveying Fluids Above Ambient Temperature:
  - 1. Provide standard jackets, with or without vapor barrier, factory-applied, or field-applied. Secure with self-sealing longitudinal laps and butt strips with pressure-sensitive adhesive. Secure with outward clinch expanding staples.
  - 2. Insulate fittings, joints, and valves with insulation of like material and thickness as adjoining pipe. Finish with glass cloth and adhesive or PVC fitting covers.
- F. Inserts and Shields:
  - 1. Application: Piping 1-1/2 inches diameter or larger.
  - 2. Shields: Galvanized steel between pipe hangers or pipe hanger rolls and inserts.
  - 3. Insert location: Between support shield and piping and under the finish jacket.
  - 4. Insert Configuration: Minimum 6 inches long, of same thickness and contour as adjoining insulation; may be factory fabricated.
- G. Continue insulation through walls, sleeves, pipe hangers, and other pipe penetrations. Finish at supports, protrusions, and interruptions.
- H. Pipe Exposed in Mechanical Equipment Rooms or Finished Spaces (less than 10 feet above finished floor): Finish with PVC jacket and fitting covers.

#### **3.03 SCHEDULE**

- A. Heating Systems:
  - 1. Minimum R-4 per inch.

2. Heating Water Supply and Return:
  - a. One and one-half inch (1-1/2") thickness on piping 1-1/2" and less.
  - b. Two inch (2") thickness on piping 2" and larger.
- B. Cooling Systems:
  1. Minimum R-4 per inch.
  2. Chilled Water:
    - a. One and one-half inch (1-1/2") thickness on piping 1-1/2" and less.
    - b. Two inch (2") thickness on piping 2" and larger.
  3. Water piping installed by this Contractor:
    - a. Three quarter inch (3/4") thickness on piping 2" and less.
    - b. One inch (1") thickness on piping 2-1/2" and larger.

**END OF SECTION**

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## DDC INPUT / OUTPUT SUMMARY TABLE

| Sauk County Courthouse<br>HVAC and Lighting<br>Upgrades<br>Project No. 2025012 |               | HARDWARE |         |  |        |  |         |        |                                    |  |  |  |  | SOFTWARE |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|                                                                                | OUTPUT        |          | INPUT   |  |        |  | ALARMS  |        |                                    |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|                                                                                | DIGITAL       | ANALOG   | DIGITAL |  | ANALOG |  | DIGITAL | ANALOG | ENERGY MANAGEMENT SYSTEM FUNCTIONS |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| SYSTEM: Hot Water System                                                       | Control Relay |          |         |  |        |  |         |        |                                    |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

### DDC INPUT / OUTPUT SUMMARY TABLE

| Sauk County Courthouse<br>HVAC and Lighting Upgrades<br>Project No. 2025012 | HARDWARE      |       |         |                |                    |                          |           |             |                        |                       |                |                   |                      |             |             |                   |                       |        | SOFTWARE        |      |                  |             |                                    |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |    |
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|                                                                             | OUTPUT        |       |         |                |                    |                          |           |             | INPUT                  |                       |                |                   |                      |             |             |                   |                       |        | ALARMS          |      |                  |             |                                    |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |    |
|                                                                             | DIGITAL       |       |         |                | ANALOG             |                          |           |             | DIGITAL                |                       |                |                   | ANALOG               |             |             |                   |                       |        | DIGITAL         |      | ANALOG           |             | ENERGY MANAGEMENT SYSTEM FUNCTIONS |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |    |
|                                                                             | Control Relay | 24VAC | Contact | 2-Pos Actuator | Tri-State Actuator | Duration Adjust Actuator | 1-44-5VDC | 0(2)-10 VDC | Current Sensing Switch | Control Relay Contact | Switch Closure | Auxiliary Contact | Diff Pressure Switch | Flow Switch | Temperature | Relative Humidity | Differential Pressure | 0-5VDC | Static Pressure | Flow | Equipment Status | Maintenance | Pressure                           | High Limit | Low Limit | Maintenance | Day/Night Setback | Demand Limiting | Dial-up I/O | Duty Cycling | Optimum Start/Stop | Scheduled Start/Stop | Totalization | Trend | Equipment Integration | Fire Alarm Integration | Security/Access Integration | Elect PQM Integration | Chiller Integration | Dry-bulb Economizer | HW/OA Reset | CHW Reset | Smoke Control | Fire Alarm Override |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |    |
| SYSTEM: RTU-1                                                               |               |       |         |                |                    |                          |           |             |                        |                       |                |                   |                      |             |             |                   |                       |        |                 |      |                  |             |                                    |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | </ |

### DDC INPUT / OUTPUT SUMMARY TABLE

| Sauk County Courthouse<br>HVAC and Lighting Upgrades<br>Project No. 2025012 | HARDWARE      |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      | SOFTWARE         |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
|-----------------------------------------------------------------------------|---------------|-------|---------|----------------|--------------------|--------------------------|---------|----------|------------------------|-----------------------|----------------|-------------------|----------------------|-------------|-------------|-------------------|-----------------------|----------------|------------------------------------|------|------------------|-------------|----------|------------|-----------|-------------|-------------------|-----------------|-------------|--------------|--------------------|----------------------|--------------|-------|-----------------------|------------------------|-----------------------------|-----------------------|---------------------|---------------------|-------------|-----------|---------------|---------------------|----------|---|--|---------------------|--|
|                                                                             | OUTPUT        |       |         |                |                    |                          |         | INPUT    |                        |                       |                |                   |                      |             | ALARMS      |                   |                       |                |                                    |      |                  |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
|                                                                             | DIGITAL       |       |         | ANALOG         |                    |                          |         | DIGITAL  |                        |                       |                | ANALOG            |                      |             | DIGITAL     |                   | ANALOG                |                | ENERGY MANAGEMENT SYSTEM FUNCTIONS |      |                  |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
|                                                                             | Control Relay | 24VAC | Contact | 2-Pos Actuator | Tri-State Actuator | Duration Adjust Actuator | 4-20 mA | 0-10 VDC | Current Sensing Switch | Control Relay Contact | Switch Closure | Auxiliary Contact | Diff Pressure Switch | Flow Switch | Temperature | Relative Humidity | Differential Pressure | Gauge Pressure | Static Pressure                    | Flow | Equipment Status | Maintenance | Pressure | High Limit | Low Limit | Maintenance | Day/Night Setback | Demand Limiting | Dial-up I/O | Duty Cycling | Optimum Start/Stop | Scheduled Start/Stop | Totalization | Trend | Equipment Integration | Fire Alarm Integration | Security/Access Integration | Elect PQM Integration | Chiller Integration | Dry-bulb Economizer | HW/OA Reset | CHW Reset | Smoke Control | Fire Alarm Override | Comments |   |  |                     |  |
| SYSTEM: AHU-1,2,3, RAHU-1,2<br>(mixed air VAV electrically actuated)        |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      | X           |             |                   |                       |                |                                    |      |                  |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| POINT DESCRIPTION                                                           |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             | X           |                   |                       |                |                                    |      |                  |             |          | X          | X         |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Supply Air Temperature                                                      |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             | X           |                   |                       |                |                                    |      |                  |             |          | X          | X         |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Mixed Air Temperature                                                       |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             | X           |                   |                       |                |                                    |      |                  |             |          | X          | X         |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Return Air Temperature                                                      |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             | X           |                   |                       |                |                                    |      |                  |             |          | X          | X         |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Return Air Rel Humidity                                                     |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             | X                 |                       |                |                                    |      |                  |             |          | X          | X         |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Heating Coil Valve                                                          |               |       |         |                |                    |                          | X       |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Heating Coil Pump Start/Stop                                                | X             |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  | X           |          |            |           |             |                   |                 |             |              |                    |                      |              |       | X                     |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Heating Coil Pump Status                                                    |               |       |         |                |                    |                          |         | X        |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  | X           |          |            |           |             |                   |                 |             |              |                    |                      |              |       | X                     |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Chilled Water Coil Valve                                                    |               |       |         |                |                    |                          | X       |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       | X                     |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Chilled Water Coil Temperature                                              |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             | X           |                   |                       |                |                                    |      |                  |             | X        | X          |           |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Return Air Damper                                                           |               |       |         |                |                    |                          | X       |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       | X                     |                        |                             |                       | X                   |                     |             |           |               |                     |          |   |  |                     |  |
| Relief Air Damper                                                           |               |       |         |                |                    |                          | X       |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       | X                     |                        |                             |                       | X                   |                     |             |           |               |                     |          |   |  |                     |  |
| Outdoor Air Damper                                                          |               |       |         |                |                    |                          | X       |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       | X                     |                        |                             |                       | X                   |                     |             |           |               |                     |          |   |  |                     |  |
| Minimum OA Flow                                                             |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             |                   |                       |                | X                                  |      |                  |             | X        | X          |           |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Supply Fan VFD Speed                                                        |               |       |         |                |                    |                          | X       |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Supply Fan VFD Fault                                                        |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      | X                |             |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       | X                      |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Supply Fan Status                                                           |               |       |         |                |                    |                          |         | X        |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      | X                |             |          |            |           |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Supply Fan Start/Stop                                                       | X             |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  |             |          |            |           |             |                   |                 |             |              |                    | X                    | X            |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Supply Air Static Pressure                                                  |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             |                   |                       | X              |                                    |      |                  |             | X        |            |           |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Relief Fan VFD Speed                                                        |               |       |         |                |                    |                          | X       |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  | X           |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       | X                      |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Relief Fan VFD Fault                                                        |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  | X           |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Relief Fan Status                                                           |               |       |         |                |                    |                          |         | X        |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  | X           |          |            |           |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Relief Fan Start/Stop                                                       | X             |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             |                   |                       |                |                                    |      |                  |             |          |            |           |             |                   |                 |             |              | X                  | X                    |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Building Static Pressure                                                    |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             |                   |                       | X              |                                    |      |                  |             | X        |            |           |             |                   |                 |             |              |                    |                      |              | X     |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Prefilter Differential Pressure                                             |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             |                   | X                     |                |                                    |      |                  |             | X        |            | X         |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Final-filter Differential Pressure                                          |               |       |         |                |                    |                          |         |          |                        |                       |                |                   |                      |             |             | X                 |                       |                |                                    |      |                  |             | X        |            | X         |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| High Press Static Shutdown                                                  |               |       |         |                |                    |                          |         |          |                        |                       | X              |                   |                      |             |             |                   |                       |                |                                    |      |                  | X           | X        |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  |                     |  |
| Freeze Stat                                                                 |               |       |         |                |                    |                          |         |          |                        |                       | X              |                   |                      |             |             |                   |                       |                |                                    |      |                  | X           |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          |   |  | Electric freezestat |  |
| Fire Alarm Shutdown                                                         |               |       |         |                |                    |                          |         |          |                        |                       | X              |                   |                      |             |             |                   |                       |                |                                    |      |                  | X           |          |            |           |             |                   |                 |             |              |                    |                      |              |       |                       |                        |                             |                       |                     |                     |             |           |               |                     |          | X |  |                     |  |

## DDC INPUT / OUTPUT SUMMARY TABLE

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## DDC INPUT / OUTPUT SUMMARY TABLE

[illegible]

### DDC INPUT / OUTPUT SUMMARY TABLE

| Sauk County Courthouse<br>HVAC and Lighting Upgrades<br>Project No. 2025012 | HARDWARE      |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             | SOFTWARE    |           |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
|-----------------------------------------------------------------------------|---------------|----------|---------|--------|--------------------|--------------------------|---------|----------|------------------------|-----------------------|----------------|-------------------|----------------------|-------------|-------------|-----------|-----------------------|-------------------|------------------------------------|------|------------------|-------------|----------|------------|-----------|---|--|--|-------------------|-----------------|-------------|--------------|--------------------|--------------------|--------------|-------|--------------------|----------------------|------------------------|-----------------------------|-----------------------|---------------------|------------|------------|-----------|---------------|---------------------|----------|--|
|                                                                             | OUTPUT        |          |         |        |                    |                          |         | INPUT    |                        |                       |                |                   |                      |             | ALARMS      |           |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
|                                                                             | DIGITAL       |          |         |        | ANALOG             |                          |         | DIGITAL  |                        |                       |                | ANALOG            |                      |             | DIGITAL     | ANALOG    |                       |                   | ENERGY MANAGEMENT SYSTEM FUNCTIONS |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
|                                                                             | Control Relay | Solenoid | Contact | 24 VAC | Tri-State Actuator | Duration Adjust Actuator | 4-20 mA | 0-10 VDC | Current Sensing Switch | Control Relay Contact | Switch Closure | Auxiliary Contact | Diff Pressure Switch | Flow Switch | Temperature | Resistive | Differential Pressure | Actuator Feedback | CO2                                | Flow | Equipment Status | Maintenance | Pressure | High Limit | Low Limit |   |  |  | Day/Night Setback | Demand Limiting | Dial-up I/O | Duty Cycling | Optimum Start/Stop | Scheduled Occ/Unoc | Totalization | Trend | Redundancy Control | Lighting Integration | Fire Alarm Integration | Security/Access Integration | Elect PQM Integration | Chiller Integration | CFM Offset | OA Lockout | CHW Reset | Smoke Control | Fire Alarm Override | Comments |  |
| SYSTEM: VAV, HW Heating Coils                                               |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             |             |           |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| POINT DESCRIPTION                                                           |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             |             |           |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| VAV                                                                         |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             |             |           |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Zone Temperature                                                            |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             | X           |           |                       |                   |                                    |      |                  |             |          |            | X         | X |  |  |                   |                 |             |              |                    | X                  |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Temperature Setpoint Adjust                                                 |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             |             | X         |                       |                   | X                                  |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Supply Air Damper <sup>1 &amp; 2</sup>                                      |               |          |         |        | X                  | X                        | X       | X        |                        |                       |                |                   |                      |             |             |           |                       | X                 |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Supply Air Flow                                                             |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             |             |           |                       |                   |                                    | X    |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    | X            |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Discharge Air Temperature                                                   |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             | X           |           |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              | X     |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Reheat Valve                                                                |               |          |         |        |                    |                          |         | X        |                        |                       |                |                   |                      |             |             |           | X                     |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              | X     |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Radiant Heat Valve                                                          |               |          |         |        | X                  |                          | X       |          |                        |                       |                |                   |                      |             |             |           |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Occupancy Sensor                                                            |               |          |         |        |                    |                          |         |          |                        |                       | X              |                   |                      |             |             |           |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
|                                                                             |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             |             |           |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Zone Heating Coils                                                          |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             |             |           |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Zone Temperature                                                            |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             | X           |           |                       |                   |                                    |      |                  |             |          |            | X         | X |  |  |                   |                 |             |              |                    |                    | X            |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Temperature Setpoint Adjust                                                 |               |          |         |        |                    |                          |         |          |                        |                       |                |                   |                      |             |             | X         |                       |                   |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              |       |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |
| Reheat Valve                                                                |               |          |         |        |                    |                          | X       |          |                        |                       |                |                   |                      |             |             |           |                       | X                 |                                    |      |                  |             |          |            |           |   |  |  |                   |                 |             |              |                    |                    |              | X     |                    |                      |                        |                             |                       |                     |            |            |           |               |                     |          |  |

Notes:

1. Analog outputs must utilize a calculated proportional command from software. Actual output can be any type but floating outputs shall have a means of indicating actual actuator position to BAS
2. Damper actuators can utilize stepper type motors.

## **SECTION 23 09 23 - DIRECT DIGITAL CONTROL (DDC) SYSTEMS**

### **(FOR INFORMATIONAL PURPOSES ONLY)**

#### **PART 1 GENERAL**

##### **2.01 SCOPE**

- A. The work associated with this section WILL NOT be bid as part of the Division 23 scope of work.
- B. Work in this section includes Direct Digital Control (DDC) panels, main communication trunk, software programming, and other equipment and accessories necessary to constitute a completely coordinated extension of the existing campus or building Direct Digital Control (DDC) system. This system interfaced with pneumatic/electric controls (Section 23 09 54) utilizing Direct Digital Control signals to operate actuated control devices will meet, in every respect, all operational and quality standards specified herein, a fully coordinated modification and extension via DDC of the existing Central Campus Automation System.

##### **2.02 RELATED WORK**

- A. Applicable provisions of Division 1 shall govern work under this section.
- B. Section 23 09 15 – DDC Points List
- C. Section 23 09 54 –Electric Temperature Control System.
- D. Section 23 09 93 - Automatic Control Sequences.
- E. Division 23 - HVAC - Equipment provided to be controlled or monitored
- F. Division 26 - Electrical - Equipment provided to be controlled or monitored

##### **2.03 REFERENCE**

- A. Applicable provisions of Division 1 govern work under this section.

##### **2.04 REFERENCE STANDARDS**

- A. FCC Part 15, Subpart J, Class A - Digital Electronic Equipment to Radio Communication Interference

##### **2.05 WORK NOT INCLUDED**

- A. Section 23 09 54 work includes furnishing and installing all field devices, including electronic sensors for the DDC of this section, equipment, and all related field wiring, interlocking control wiring between equipment, pneumatic tubing, sensor mounting, etc., that is covered in that section.
- B. Motorized control dampers and actuators, thermowells (temperature sensing wells), automatic control valves and their actuators are also covered in Section 23 09 54.

##### **2.06 QUALITY ASSURANCE**

- A. Manufacturer:

1. Johnson Controls Metasys, utilizing BACnet communication protocol.
- B. Original Equipment Manufacturer (OEM) Controller DDC Integration: Where factory-packaged controls are furnished for DDC of HVAC equipment and devices, a manufacturer's branch office or an authorized representative of the equipment manufacturer shall provide start-up and check-out of equipment and shall work with this contractor for integration to the Building Automation System (where integration is specified). OEM shall provide tech support as needed until integration is complete and operating reliably.
- C. Installer:
  1. A firm specializing and experienced in DDC control system installation for no less than 3 years. All engineering and commissioning work shall be done by qualified employees of this manufacturer, or qualified employees of an Authorized Representative of that manufacturer that provides engineering and commissioning of the manufacturer's control equipment. Where installing contractor is an authorized representative of the control equipment manufacturer, submit written confirmation of such authorization. Indicate in letter of authorization that the installing contractor has successfully completed all necessary training required for the engineering, installation, and commissioning of equipment and systems to be provided for the project and that such authorization has been in effect for a period of not less than three years. The letter of authorization should also indicate that the installing contractor is authorized to install the manufacturer's DDC equipment at the project location at the time the project is bid. Installation of the equipment shall be done by qualified mechanics and/or electricians in the direct employ or be directly subcontracted and under the supervision of the manufacturer or Authorized Representative. The contractor providing and installing the equipment under this specification section shall be the same contractor providing and installing equipment under the 23 09 54 specification section.
- D. Response Time:
  1. During warranty period, 4 hours or less, 24-hours/day, 7 days/week.
- E. Electrical Standards:
  1. Provide electrical products, which have been tested, listed and labeled by Underwriters' Laboratories (UL) and comply with NEMA standards.
  2. DDC Standards: DDC manufacturer shall provide written proof with shop drawings that the equipment being provided is in compliance with F.C.C. rules governing the control of interference caused by Digital Electronic Equipment to Radio Communications (Part 15, Subpart J, Class A).

## **2.07 SUBMITTALS**

- A. The following sections shall be submitted together as one package: 23 09 15, 23 09 23, 23 09 54, and 23 09 93. All four specification sections shall be referenced on submittal cover page and paperwork. Include the following information (see 23 09 54 for additional requirements):
1. Details of construction, layout, and location of each temperature control panel within the building, including instruments location in panel and labeling. Indicate which piece of mechanical equipment is associated with each controller and what area within the building is being served by that equipment. For terminal unit control, provide a room schedule that would list mechanical equipment tag, room number of space served, address of DDC controller, and any other pertinent information required for service.
  2. A schedule of all inputs and outputs associated with DDC controllers for project.
  3. Sequence of operations for all DDC equipment, including Original Equipment Manufacturer DDC packaged controllers. It is this contractor's responsibility to obtain the OEM equipment sequence and include it in the submittal package so all DDC under the Building Automation System can be referenced in one, cohesive package.
  4. **PRODUCT DATA**
    - a. Submit manufacturer's specifications for each control device furnished, including installation instructions and startup instructions. General catalog sheets showing a series of the same device is not acceptable unless the specific model is clearly marked. Actual system sequences, along with descriptive narratives of the sequence of operation of the entire system involved. Submit wiring diagram for each electrical control device along with other details required to demonstrate that the system has been coordinated and will function as a system.
  5. **MAINTENANCE DATA**
    - a. Submit maintenance data and spare parts lists for each control device. Include this data in maintenance manual.

## **2.08 RECORD DRAWINGS**

- A. Prior to request for final payment provide complete composite record drawings to incorporate the DDC and Pneumatic/Electric field work. Accurate Section 23 09 54 record drawings to be supplied by the Section 23 09 54 contractor with the accuracy of these drawings being the responsibility of the 23 09 54 contractor. In the event that changes are required to the 23 09 54 supplied record drawings after they have been compiled by the 23 09 23 contractor, it shall be the 23 09 54 contractor's responsibility to provide updated composite record drawings incorporating the 23 09 23 record drawings.

- B. All software addressing for device communication shall be noted for all devices provided under this section and the communication addressing required for devices provided by others that are integrated into the direct digital control system provided under this section. Point to point routing of communication trunks and power wiring between DDC controllers, DDC communication devices, control panels, and Ethernet switches shall be documented. For systems that have additions to existing communication networks, provide complete DDC network diagrams for the communication trunk affected with new work clearly delineated. Coordinate with the supplier of the equipment specified to be interfaced through digital communications for communication addressing. Provide circuit number of 120VAC panel power circuit(s) feeding each control panel on record drawings. Label circuit number(s) inside the panel served.
- C. Any supervisory controller (new or existing) is to be identified by its controller type, controller address and communication trunk type and controller location. It shall also identify all (new or existing) field controllers by controller type, controller address and communication trunk type and controller location. Asbuilts of controller-to-controller communication trunk and network trunk layout must be provided.
- D. Operation and Maintenance Data:
  - 1. All operations and maintenance data shall comply with the submission and content requirements specified under section GENERAL REQUIREMENTS.
  - 2. In addition to the general content specified under GENERAL REQUIREMENTS supply the following additional documentation:
    - a. Provide signed and dated commissioning sheets. Commissioning sheets shall include both DDC point-to-point checkoff (confirming all DDC points are accurate and operable) and Functional Performance Testing checkoff sheets (confirming equipment operates according to sequence of operations). These are required in addition to any general commissioning requirements specified elsewhere.
    - b. In each temperature control panel, provide a copy of the control drawings that pertain to equipment served by the temperature control panel. This should include a flow schematic of the system(s) served, the control panel and field wiring diagrams (furnished by 23 09 54), and the sequence of operations.

## **2.09 MATERIAL DELIVERY AND STORAGE**

- A. Provide factory shipping cartons for each piece of equipment and control device. This contractor is responsible for storage of equipment and materials inside and protected from the weather.

## **PART 2 PRODUCTS**

### **3.01 GENERAL**

- A. Provide DDC control products in sizes and of capacities as required, conforming to manufacturer's standard materials and components as published in their product information, designed and constructed as recommended by the manufacturer and as required for application indicate.
- B. System shall be capable of operating with 120 VAC power supply, fully protected with a shutdown-restart circuit, and associated hardware and software.

### **3.02 LOCAL CONTROL PANELS**

- A. Use control panels with suitable mounting brackets for each supply fan system. Locate panel adjacent to system served or where shown on plans.
- B. Fabricate panels of 14 gauge furniture grade steel or 6063-T5 extruded aluminum alloy, totally enclosed on six sides, hinged door and keyed lock, with manufacturer's standard shop painted finish and color.
- C. Provide UL listed cabinets for use with line voltage devices.
- D. Control panels that have devices or terminations that are fed or switch 50V or higher shall enclose the devices, terminations, and wiring so that Personal Protective Equipment (PPE) is not required to service the under 50V devices and terminations within the control panel. As an alternative, a separate panel for only the 50V and higher devices may be provided and mounted adjacent to the under 50V control panel.
- E. Plastic control enclosures will be approved provided all conduits are bonded and grounded.
- F. Provide control panels for all DDC Controllers, ASC's and associated function modules. All controls to be in control panels provided under this Section except for the following:
  - 1. Terminal unit controllers mounted within the terminal unit equipment enclosure
    - a. or above/beneath accessible lay-in tile ceilings/floors where VAV box controllers designed to be directly mounted on air terminals.
  - 2. Above/below accessible lay-in tile ceilings/floors where additional controllers are required for air terminal unit control. Where additional controllers are required, they shall not be mounted directly to the ductwork but be mounted on din rail or back panel in an accessible location as close as possible to the terminal unit(s) being controlled.
- G. Provide terminal unit equipment enclosures with removable cover for all terminal units located in exposed ceilings or in mechanical rooms that completely enclose the DDC controller and allow for conduit terminations.
- H. All wiring for controllers shall be managed in a neat and workmanlike manner.

- I. Permanently label all controls: Tag all control wiring with associated DDC point name. If wiring is not associated with DDC point name, tag control wiring with an intuitive name indicating its purpose, and document on all control drawings.

### **3.03 DIRECT DIGITAL CONTROLS**

- A. System to be capable of integrating multiple building functions, including equipment supervision and control, alarm management, energy management, and trend data collection.
- B. DDC to consist of Supervisory Controllers, Programmable Controllers, stand-alone Application Specific Controllers (ASC's), Operators Terminals, Operator Workstations, DDC system servers, and other operator interface devices.
- C. The system shall be modular in nature, and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, ASC's, and operator devices.
- D. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

### **3.04 NETWORKING/COMMUNICATIONS**

- A. The design of the DDC shall be networked. The highest level networking shall use Ethernet and the sub-level networking shall use serial communications. Inherent in the system's design shall be the ability to expand or modify the highest network either via a local area network (LAN), wide area network (WAN), or a combination of the two schemes.
- B. The highest-level DDC communications network shall be capable of direct connection to and communication with a high-speed LAN or WAN utilizing an Ethernet connection.  
Communication protocol used shall be BACnet/IP.
- C. The supervisory controller shall directly oversee a local network such that communications may be executed directly to and between programmable controllers and ASC's. All operator devices, either network resident or connected via dial-up modems, shall have the ability to access all points and application reports on the network.
- D. Provide serial communication ports on all ASC's for operator's terminal communications with the DDC Controller.
- E. Access to system data shall not be restricted by the hardware configuration of the DDC system.
- F. Global data sharing or global point broadcasting shall allow point data to be shared between programmable controllers and ASC's when it would be impractical to locate multiple sensors.
- G. BACnet Requirements:
  1. BACnet of highest level network communications will utilize BACnet/IP over Ethernet and field level communications shall utilize BACnet MSTP. No other communication protocol is acceptable.

2. All controllers shall provide a Protocol Implementation Conformance Statement (PICS) and BACnet Interoperability Building Blocks (BIBB"S) as required by the American National Standards Institute/American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ANSI/ASHRAE) Standard 135-2001, BACnet protocol.
- H. Supervisory controllers shall be microprocessor-based, multi-tasking, multi-user and digital control processors.
- I. Each supervisory controller shall have sufficient memory to support its own operating system and databases including:
  1. Control processes.
  2. Energy management application.
  3. Alarm management.
  4. Trend data.
  5. Maintenance support applications.
  6. Operator I/O.
  7. Dial-up communications.
  8. Manual override monitoring.
- J. The system shall be modular in nature, and shall permit easy expansion through the addition of field controllers, sensors, and actuators.
- K. Supervisory controllers shall provide at least two RS-232C or USB serial communication ports or Ethernet ports for simultaneous operation of multiple operator I/O devices, such as laptop computers, personal computers, and video display terminals.
- L. Supervisory controllers shall monitor the status of all overrides and include this information in the logs and summaries to inform the operator that automatic control has been inhibited.
- M. Each supervisory controller shall continuously perform self-diagnostics, communications diagnostics, and diagnostics of all subsidiary equipment. Supervisory controllers shall provide both local and remote annunciation of any detected component failures, or repeated failure to establish communication. Indication of the diagnostic results shall be provided at each supervisory controller.
- N. Isolation shall be provided at all network terminations, as well as all field point terminations, to suppress induced voltage transients consistent with IEEE Standard 587-1980. Isolation levels shall be sufficiently high to allow all signal wiring to be run in the same conduit as high voltage wiring acceptable by electrical code.
- O. In the event of the loss of normal power, there shall be an orderly shutdown of the supervisory controller to prevent the loss of data base or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data, and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.

- P. Upon restoration of normal power, the supervisory controller shall automatically resume full operation without manual intervention.
- Q. Should supervisory controller memory be lost for any reason, the supervisory controller shall have the capability of reloading it's programming via high speed local area network from the control system archive workstation or server, the local RS-232C port, or telephone line dial-in.

### **3.05 SYSTEM SOFTWARE FEATURES**

- A. All necessary software to form a complete operating system, as described in this specification, shall be provided as an integral part of the supervisory controller, and shall not be dependent upon higher level computer for execution.
- B. Control software shall include a provision for limiting the number of times that each piece of equipment may be cycled within any one-hour period.
- C. The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads.
- D. Supervisory controllers shall have the ability to perform any or all of the following energy management routines:
  - 1. Time of day scheduling.
  - 2. Calendar based scheduling.
  - 3. Holiday scheduling.
  - 4. Optimal start.
  - 5. Optimal stop.
  - 6. Demand limiting.
  - 7. Load rolling.
  - 8. Heating/cooling interlock.
- E. All programs to be executed automatically without the need for operator intervention, and be flexible enough to allow user customization. Programs shall be applied to building equipment described in Section 23 09 93 of this specification.
- F. Supervisory controllers shall be able to execute configured processes defined by the user to automatically perform calculations and control routines.
- G. It shall be possible to use any of the following in a configured process:
  - 1. Any system-measured point data or status.
  - 2. Any calculated data.
  - 3. Any results from other processes.
  - 4. Boolean logic operators (and, or).
- H. Configured processes may be triggered based on any combination of the following:
  - 1. Time of day.
  - 2. Calendar date.

3. Other processes.
4. Events (e.g., point alarms).
- I. A single process shall be able to incorporate measured or calculated data from any and all other ASC's.
- J. A single process shall be able to issue commands to points in any and all other programmable controllers and ASC's on the local network.
- K. Alarm management shall be provided to monitor, buffer, and direct alarm reports to operator devices and memory files. Each supervisory controller shall perform distributed; independent alarm analysis and filtering to minimize network traffic and prevent alarms from being lost. At no time shall the ability of supervisory controllers to report alarms be affected by either operator activity at the local I/O device or communications with other ASC's on the network.
- L. All alarm or point change reports shall include the English language description of each point and the time and date of the occurrence.
- M. The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of three priority levels shall be provided. Users shall have the ability to manually inhibit alarm reporting for each point.
- N. The user shall also be able to define conditions under which point changes need to be acknowledged by an operator and/or logged for analysis at a later date.
- O. Alarms reports and messages shall be directed to an operator device.
- P. In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 60-character alarm message to more fully describe the alarm condition or direct operator response.
- Q. Each supervisory controller shall be capable of storing a library of at least 100 messages. Each message may be assignable to any number of points in the panel.
- R. A data collection utility shall be provided to automatically sample, store, and display system data.
- S. Measured and calculated analog and binary data shall be assignable to user definable trends for the purpose of collecting operator specified performance data over extended periods of time. Sample intervals of 1 minute to 24 hours, in one minute or one hour intervals, shall be provided. Each supervisory controller shall have a dedicated buffer for trend data and shall be capable of storing 16 trend logs. Each trend log shall have up to four points trended at 48 data samples each. Data shall be stored at the supervisory controller and up-loaded to the DDC system server when archiving is desired.
- T. Supervisory controllers shall automatically accumulate and store runtime hours for binary input and output points, specified in Sections 23 09 15 and 23 09 54, of this specification.

- U. Supervisory controllers shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis, user defined, for user-selected analog and binary pulse input type points.
- V. Totalization shall provide calculation and storage accumulations of up to 9,999,999 units (e.g., KWH, gallons KBTU, tons, etc.).
- W. The totalization routine shall have a sampling resolution of one minute.
- X. The user shall have the ability to define a warning limit. Unique, user specified messages shall be generated when the limit is reached.
- Y. The information available from pulse totalization shall include, but not be limited to, the following:
  - 1. Peak demand, with date and time stamp.
  - 2. 24-hour demand log.
  - 3. Accumulated KWH for day.
  - 4. Sunday through Saturday KWH usage.
  - 5. Demand KW annual history for past 12 periods.
  - 6. KWH annual history for past periods.
- Z. Supervisory controllers shall have the ability to count events, such as the number of times a pump or fan system is cycled on and off.
- AA. The event totalization feature shall be able to store the records associated with a minimum of 9,999,999 events before reset.

### **3.06 PROGRAMMABLE CONTROLLERS**

- A. Programmable controllers shall be provided with a software program that shall allow the user to design flexible software algorithms for the control sequences as described in Sections 23 09 54 and 23 09 93, portions of this specification.
- B. Programmable controllers shall support all necessary point inputs and outputs to perform the specified control sequence in a totally stand-alone fashion.
- C. Each programmable controller shall perform its own limit and status monitoring and analysis to maximize network performance by reducing unnecessary communications.
- D. Each programmable controller shall support the use of a locally mounted status and adjust panel interface to allow for the local adjustment of all setpoints, temporary override of any input or output points and status of all points directly at the controller. The capabilities of the locally mounted status and adjust panel shall include, but not be limited to, the following information for the programmable controllers to which:
  - 1. Display temperatures.
  - 2. Display status.
  - 3. Display setpoints.
  - 4. Display control parameters.

5. Override binary output control.
  6. Override analog output control.
  7. Override analog setpoints.
  8. Modification of gain and offset constants.
- E. All system setpoints, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the programmable controller.
- F. Programmable controllers shall support, but not be limited to, the following configurations of systems to address current requirements as described in Sections 23 09 54 and 23 09 93, portions of this specification:
1. Mixed air handling units.
  2. hot water heating systems with pump logic.

### **3.07 APPLICATION SPECIFIC CONTROLLERS - HVAC APPLICATIONS**

- A. Each supervisory controller shall be able to extend its monitoring and control through the use of stand-alone application specific controllers (ASC's).
- B. Each ASC shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each ASC shall be a microprocessor based, multi-tasking, real-time digital control processor.
- C. Each ASC shall have sufficient memory to support its own operating system and databases including:
1. Control Processes.
  2. Energy Management Applications.
  3. Operator I/O (Portable Service Terminal).
- D. The operator interface to any ASC point or program shall be through the supervisory controller connection to any ASC on the network.
- E. ASC's shall directly support the temporary use of a portable service terminal that can be connected to the ASC via zone temperature or directly at the controller. The capabilities of the portable service terminal shall include, but not be limited to, the following information for the:
1. Display temperatures.
  2. Display status.
  3. Display setpoints.
  4. Display control parameters.
  5. Override binary output control.
  6. Override analog output control.
  7. Override analog setpoints.
  8. Modification of gain and offset constants.

- F. All system setpoints, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the ASC.
- G. ASC's shall support, but not be limited to, the following configurations of systems to address current requirements as described in Sections 23 09 54 and 23 09 93, portions of this specification, and for future expansion of air handling units:
  - 1. Variable Air Volume Terminals.
  - 2. Reheat Terminals.
  - 3. Fan Coils.
  - 4. Unit Ventilators.
  - 5. Packaged Air Handling Units.
- H. For butterfly type Variable Air Volume (VAV) Terminals, provide differential pressure transducers and damper actuators for flow measurement and actuation of the VAV terminal damper. Pressure transducers for VAV box flow applications do not need to have adjustable pressure ranges or integral display. Provide filter on high side of flow pickups if flow measurement device requires airflow through the device. All differential pressure transducer inputs for airflow measurement shall have a method to compensate for sensor drift to calibrate the zero point of the input. The differential pressure transducers and damper actuators can be integrated into the terminal unit controller or be discrete devices.
- I. Provide a method to view and print a summary of current K-factors for flow correction for each VAV terminal through the DDC system. The summary shall have a minimum of 50 K-factors per group of VAV terminals.
- J. All system setpoints, proportional bands, control algorithms, calibration constants, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the ASC.
- K. All application specific controllers shall be fully programmable. Question and answer or template programming is not acceptable unless this is used to generate the initial application program and the result is able to be freely modified without restriction. Control sequences for terminal unit control that utilize devices wired directly to the terminal unit application controller shall be programmed in the application specific controller and shall be stand-alone in function, i.e. occupancy sensing, temperature setpoint setback, etc. Supervisory controllers shall not be involved in the control sequence logic unless it involves sharing data between or from individual terminal unit controllers to be utilized in a global sequence, i.e. trim and respond strategies, terminal unit grouping, etc.

### **3.08 OPERATOR INTERFACE REQUIREMENTS**

- A. Text-based Displays: The operator interface shall provide consistent text-based displays of all system point and application data described in this specification. Point identification, engineering units, status indication, and application naming conventions shall be the same at all operator devices.
- B. Graphic-based Displays: The operator interface shall provide MUI graphic based displays of each system and the existing graphics shall be modified to remove no longer applicable equipment and points. The point data associated with each system shall dynamically update at a minimum of every 30 seconds. Graphic displays shall be linked to each other to provide a “drill down” capability from main graphic displays to more specific system based displays. Provide a building level graphic display that links to system graphics. For systems that have ASC controlled terminal unit controls, provide a building floor plan with dynamic temperatures shown on the graphic that can be drilled into for more specific terminal information. Points provided in the graphic shall have the override and adjust capability specified under operator commands. The contractor providing the DDC system under this Section shall provide all graphic displays for the project.

## **PART 3 EXECUTION**

### **4.01 GENERAL**

- A. All electronic work required as an integral part of the Direct Digital Control system work is the responsibility of this section unless specifically indicated otherwise in this section, Section 23 09 54 - Electric Temperature Control Systems, or in Division 26.
- B. This contractor shall provide all labor, materials, engineering, software, permits, tools, checkout and certificates required to install a complete Direct Digital Control system as herein specified.
- C. Any and all points added with this project shall be grouped for display purposes into the system such that all points associated with a new or existing DDC system can appear together on the flat panel display or printed log. Assignment of points to a group shall not be restricted by hardware configuration of the points of direct digital control. It shall be possible to assign a point to appear in more than one system. An English descriptor and an alpha/numeric identifier shall identify each system.
- D. This Direct Digital Control system as herein specified shall be fully integrated and completely installed by this section. It shall include all required computer CPU software and hardware. Include the engineering, installation, supervision, calibration, software programming, and checkout necessary for a fully operational system.

#### **4.02 INSTALLATION**

- A. All work and materials are to conform in every detail to the rules and requirements of the National Electrical Code and present manufacturing standards. All wiring and cable installation shall conform with the wiring installation as specified in the installation section of Section 23 09 54 - Electric Temperature Control Systems. All material shall be UL approved.
- B. Install system and materials in accordance with manufacturer's instructions, rough-in drawings and details on drawings.
- C. Line voltage wiring to power the DDC Controllers, not provided by the Division 26 contractor, to be by this contractor. See plans for designations of location and quantity of Temperature Control Panels where power will be the responsibility of the Division 26 contractor. All others not shown shall be the responsibility of this contractor.
- D. Line voltage wiring to Temperature Control panels shall be served by permanent power – under no circumstances shall a control panel be served from receptacle power.
- E. Control panels serving equipment fed by emergency power shall also be served by emergency power.
- F. Provide uninterruptable power supplies where necessary to provide proper startup of equipment or to accomplish power restart control sequences specified.
- G. Mount control panels adjacent to associated equipment on vibration-free walls or free-standing angle iron supports. One cabinet may accommodate more than one system in same equipment room. Provide engraved plastic nameplates for instruments and controls inside cabinet and on cabinet face.
- H. Provide as-built control drawings of all systems served by each local panel in a location adjacent to or inside of panel cover. Provide a protective cover or envelope for drawings.
- I. Cable tray routing of the communication trunks is acceptable.
- J. All tubing, cable and individual wiring is to be permanently tagged, with numbers corresponding with "Record Drawings", spares are to be labelled as "Spare".
- K. Provide technician to work with air balancing contractor and/or provide balancing contractor with necessary hardware to over-ride DDC controllers for air balancing.
- L. Provide documentation to demonstrate that all points, input and output, have been checked out and verified operational, note any points not operating properly with notation of reason.
- M. For VAV Application Specific Controllers, VAV to be directly coupled to the ASC controller and must have 90-degree stroke.

#### **4.03 CONSTRUCTION VERIFICATION**

- A. Contractor shall be responsible for DDC Point-to-Point checkout of DDC System to ensure all points are operable and accurate. Contractor must generate and provide signed and dated checkoff sheets as part of the Operations and Maintenance Manuals and project closeout, indicating all equipment has been tested and verified to be working correctly. Construction Verification shall apply to this section and Sections 23 09 15, 23 09 54, and 23 09 93.

#### **4.04 FUNCTIONAL PERFORMANCE TESTING**

- A. Contractor shall be responsible for sequence of operations checkout of DDC System and stand-alone systems to ensure systems operate according to sequence of operations. All programmed control loops and modes of operation shall be verified. Contractor must generate and provide signed and dated checkoff sheets as part of the Operations and Maintenance Manuals and project closeout, indicating all equipment has been tested and verified to be working correctly. Functional Performance Testing shall apply to this section and Sections 23 09 15, 23 09 54, and 23 09 93.

#### **4.05 AGENCY TRAINING**

- A. Contractor to provide factory authorized representative and/or field personnel knowledgeable with the operations, maintenance and troubleshooting of the system and/or components defined within this section for a minimum period of 16 hours. Coordinate with owner to break hours up into small segments and span over multiple sessions.
- B. Provide troubleshooting and instruction after substantial completion and the other at the end of the warranty period. Provide required information and complete troubleshooting and inspection activity for all controls installed under Sections 23 09 23, 23 09 54, and 23 09 93. Coordinate the visit with the owner/Agency and provide an inspection report to the owner of any deficiencies found.

#### **END OF SECTION**

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**SECTION 23 09 34 - VARIABLE-FREQUENCY MOTOR CONTROLLERS FOR HVAC**

**PART 1 GENERAL**

**1.01 SECTION INCLUDES**

- A. Variable-frequency motor controllers for low-voltage (600 V and less) AC motor applications.

**1.02 RELATED REQUIREMENTS**

- A. Section 23 05 29 - Hangers and Supports for HVAC Piping and Equipment.
- B. Section 23 05 53 - Identification for HVAC Piping and Equipment: Identification products and requirements.
- C. Section 26 05 26 - Grounding and Bonding for Electrical Systems.

**1.03 ADMINISTRATIVE REQUIREMENTS**

- A. Coordination:
  - 1. Coordinate work to provide motor controllers suitable for use with actual motors to be installed.
  - 2. Coordinate work to provide controllers and associated wiring suitable for interface with control devices to be installed.
  - 3. Coordinate arrangement with dimensions and clearance requirements of actual equipment to be installed.
  - 4. Verify with manufacturer that conductor terminations are suitable for use with conductors to be installed.
  - 5. Notify Architect of conflicts with or deviations from Contract Documents. Obtain direction before proceeding with work.

**1.04 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements, for submittal procedures.
- B. Product Data: Provide manufacturer's standard catalog pages and data sheets for motor controllers, enclosures, overcurrent protective devices, and other installed components and accessories.
- C. Shop Drawings: Indicate dimensions, voltage, controller sizes, short circuit current ratings, conduit entry locations, conductor terminal information, and installed features and accessories.
  - 1. Include wiring diagrams showing factory and field connections.
- D. Operation and Maintenance Data: Include detailed information on system operation, equipment programming and setup, replacement parts, and recommended maintenance procedures and intervals.
- E. Project Record Documents: Record actual installed locations of controllers and final equipment settings.

1. Include nameplate data of actual installed motors and associated overload relay selections and settings.
2. Motor Circuit Protectors: Include magnetic instantaneous trip settings.

#### **1.05 QUALITY ASSURANCE**

- A. Comply with requirements of NFPA 70.
- B. Manufacturer Qualifications: Company specializing in manufacturing products specified in this section with minimum three years documented experience.
- C. Installer Qualifications: Company with minimum three years documented experience with variable-frequency motor control systems of similar size, type, and complexity; manufacturer's authorized installer.
- D. Product Listing Organization Qualifications: Organization recognized by OSHA as Nationally Recognized Testing Laboratory (NRTL) and acceptable to authorities having jurisdiction.

#### **1.06 DELIVERY, STORAGE, AND HANDLING**

- A. Store in clean, dry space. Maintain factory wrapping or provide additional heavy canvas or heavy plastic cover to protect units from dirt, water, construction debris, and traffic.
- B. Handle carefully in accordance with manufacturer's written instructions to avoid damage to internal components, enclosure, and finish.

#### **1.07 FIELD CONDITIONS**

- A. Maintain field conditions within required service conditions during and after installation.

#### **1.08 WARRANTY**

- A. See Section 01 78 00 - Closeout Submittals, for additional warranty requirements.

### **PART 2 PRODUCTS**

#### **2.01 MANUFACTURERS**

- A. ABB
- B. Eaton Corporation
- C. Danfoss
- D. Toshiba
- E. Yaskawa

#### **2.02 VARIABLE-FREQUENCY MOTOR CONTROLLERS**

- A. Provide variable-frequency motor control system consisting of required controller assemblies, operator interfaces, control power transformers, instrumentation and control wiring, sensors, accessories, system programming, etc. as necessary for complete operating system.
- B. Provide products listed, classified, and labeled as suitable for purpose intended.
- C. For motors as indicated on the Variable Frequency Drive schedule on the drawings.
- D. Inverters shall be PM compatible where required for electronically commutated (EC) motors.

- E. Variable frequency systems to convert the unit fan motor and/or pump motor constant 60 hertz frequency to variable speed operation with the use of adjustable frequency inverters and the necessary hardware to provide the function as herein specified.
- F. Inverters are to be mounted in a NEMA 1 type enclosure. The following equipment and features are to be incorporated in each unit:
  - 1. Minimum and maximum speed adjustments. Minimum speed is to be adjustable to 1/3 of maximum speed.
  - 2. Adjustable linear acceleration and deceleration each separately adjustable effective during manual and automatic modes of operation.
  - 3. Rectifier/Converter: Diode-based, 12-pulse type (min.).
  - 4. Adjustable current limit.
  - 5. Dual thermal overloads.
  - 6. Inherent short circuit protection and ground fault protection.
  - 7. Automatic operation from a remote 4-20 ma input signal or a 0-10 volt signal.
  - 8. BACnet integration card.
  - 9. Under-voltage and over-voltage protection and single phase protection.
  - 10. Over-temperature protection.
  - 11. Rated to provide 110% of rated current for a minimum period of one minute.
  - 12. Five percent (5%) chokes on input line and DC bus choke which will prevent damaging spikes from the transformer or from power outages.
  - 13. Inverter is to be rated for an input power to +10% and -10%.
  - 14. Door interlocked circuit breaker or fused disconnect for drive and bypass.
  - 15. Multi line LCD display for operating status, programming and fault history.
- G. The following door mounted devices:
  - 1. Power "on" light.
  - 2. Digital readout for speed, load, and input KW, and faults.
  - 3. Manual/off/automatic selector switch.
  - 4. Manual speed potentiometer or keypad adjustment for operation in the manual-normal mode.
  - 5. Diagnostic readouts.
- H. Floor stand mounting kit for free standing installation if field conditions require.
- I. All components shall be pre-mounted and wired in a single enclosure. Each inverter and any associated hardware shall receive a minimum 20-40 minute "burn-in" high temperature test period under full load in conjunction with a certified statement which indicates that all components of the unit have been tested prior to assembly. A full 3 year warranty on all parts and labor must be provided.

- J. A field service engineer of the drive manufacturer is to be provided for a minimum of 2 hours for start-up assistance and training.

### **PART 3 EXECUTION**

#### **3.01 EXAMINATION**

- A. Verify that field measurements are as indicated.
- B. Verify that ratings of controllers are consistent with indicated requirements.
- C. Verify that mounting surfaces are ready to accept controllers.
- D. Verify that conditions are satisfactory for installation prior to starting work.

#### **3.02 INSTALLATION**

- A. Install products in accordance with manufacturer's instructions.
- B. Install in accordance with NEMA IS 10034 and manufacturer's instructions.
- C. Do not exceed manufacturer's recommended maximum cable length between controller and motor.
- D. Arrange equipment to provide minimum clearances in accordance with manufacturer's instructions, NEC and NFPA 70.
- E. Provide required support and attachment in accordance with Section 23 05 29.
- F. Install controllers plumb and level.
- G. Provide grounding and bonding in accordance with Section 26 05 26.
- H. Install field-installed devices, components, and accessories.
- I. Where accessories are not self-powered, provide control power source as indicated or as required to complete installation.
- J. Set field-adjustable settings of controllers and associated components according to installed motor requirements, in accordance with recommendations of manufacturers of controller and load.

#### **3.03 ADJUSTING**

- A. Adjust tightness of mechanical and electrical connections to manufacturer's recommended torque settings.

#### **3.04 CLEANING**

- A. Clean dirt and debris from controller enclosures and components according to manufacturer's instructions.
- B. Repair scratched or marred exterior surfaces to match original factory finish.

#### **3.05 CLOSEOUT ACTIVITIES**

- A. See Section 01 78 00 - Closeout Submittals, for closeout submittals.
- B. See Section 01 79 00 - Demonstration and Training, for additional requirements.

- C. Demonstration: Demonstrate proper operation of controllers to Owner, and correct deficiencies or make adjustments as directed.
- D. Training: Train Owner's personnel on operation, adjustment, and maintenance of controllers and associated devices.
  - 1. Use operation and maintenance manual as training reference, supplemented with additional training materials as required.

**3.06 PROTECTION**

- A. Protect installed controllers from subsequent construction operations.

**END OF SECTION**

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## **SECTION 23 09 54 - ELECTRIC TEMPERATURE CONTROL SYSTEMS**

### **PART 1 GENERAL**

#### **1.01 RELATED REQUIREMENTS**

- A. Applicable provisions of Division 1 shall govern work under this section.
- B. Section 23 05 93 – Testing, Adjusting, and Balancing
- C. Section 23 09 15 – DDC Points List
- D. Section 23 09 23 - Direct Digital Control Systems
- E. Section 23 09 93 – Automatic Controls Sequences
- F. Section 23 21 13 – Hydronic Systems – for well/tap installation
- G. Section 23 33 00 – Ductwork Accessories – for airflow measuring station or control damper installation

#### **1.02 DESCRIPTION OF WORK**

- A. The intent of this project is to provide automated temperature control and a Building Automation System for the building.
- B. Provide DDC for the following HVAC systems. See sequence of operations in 23 09 93 and DDC Points List in 23 09 15 for a more comprehensive description of DDC requirements
  - 1. Hot Water System
  - 2. Chilled Water and Condenser Water System
  - 3. Qty (5) Air Handling Units
  - 4. Exhaust and Ventilation Fans
  - 5. VAV Boxes
  - 6. Fan Coil Units
  - 7. Radiant Heat
  - 8. Unit Heaters
- C. Work in the section includes:
  - 1. Includes, but is not necessarily limited to, furnishing and installing a complete, calibrated, tested, adjusted and as intended, electric control system; including all thermostats, controllers, electric actuators, valves, switches, relays, transducers, sensors, transmitters, conduit, wiring and other equipment and accessories necessary to constitute a complete and coordinated automatic electric temperature control system, as described herein and shown on the drawings.
  - 2. Control and data wiring, except for power wiring, necessary for electric or electronic temperature control systems, is work of this section. Electrical work under this section shall be performed in accordance of Division 26 requirements.
  - 3. Automatic Control Dampers shall be furnished by this section and installed as a part of the Division 23 Work.

4. Thermowells (Temperature Sensing Wells), Automatic Control Valves, hydronic pressure sensors, and hydronic flow sensors/meters shall be furnished by this section and installed as a part of Division 23 Work.
  5. All control systems identified in Section 23 09 93 - Automatic Control Sequences is exclusively work of this section.
  6. Analog input signals and binary input signals shall be transmitted to the Direct Digital Control systems using electronic equipment, sensors, transmitters and transducer specified herein. The DDC system shall transmit binary and/or analog output signals to equipment to obtain specified control sequences.
  7. All controls installation, furnishing of devices, software, and programming, etc. shall be furnished, except where already included with packaged control systems. Graphics shall be provided for both directly controlled equipment and integrated equipment.
  8. Temperature Control Panels shown on the Mechanical Plans shall reuse the existing 120V power to the panel. This contractor shall be responsible for all other 120VAC power, not provided in the Division 26 specifications, required for equipment provided in this section.
- D. Work not included in this section:
1. Direct digital controls and energy management interface, as specified in Section 23 09 23.
  2. Refer to Division 26 sections for power wiring to line voltage devices.
  3. Access doors are not included under this section, but are included under Division 23.
  4. The installation of automatic control dampers, air flow stations, and air flow valves is part of the sheetmetal work of Division 23.
  5. The installation of thermowells, automatic control valves, wet-media sensors, flow meters, and wet-media transmitters is part of the piping work of Division 23.
- E. Reuse of existing controls infrastructure:
1. See 23 09 15 DDC Points List for a description on expectation of reusing or replacing controls devices.
  2. Temperature Control Panel enclosures are expected to be reused at their existing locations, reusing the 120V at the panel locations. Furnish new mounting backplates to house all new DDC and associated relays, power supplies, etc. and replace contents of existing control panel. Where enclosure size is insufficient for design needs, furnish additional temperature control panels as needed.
  3. Existing conduit containing HVAC controls wiring may be reused.
  4. Reuse of control wiring between the temperature control panel and the field device may be reused if deemed in good condition and meets specifications of Distech DDC and associated field components.
- F. Demolition of existing controls infrastructure:

1. Remove all existing DDC, power supplies, and associated controls components that are to be replaced as part of this project. Maintain integrity of existing DDC field communication trunk for continuation of service during phased approach to DDC replacement.
2. Metasys Network Automation Engines (NAE) shall be demo'd last, after all DDC has been converted to Distech. Turn NAEs over to owner.

### **1.03 REFERENCE STANDARDS**

- A. NFPA 70 - National Electrical Code.
- B. ANSI B16.22 Wrought Copper and Wrought Copper Alloy Solder Joint Pressure Fittings
- C. ANSI/ASTM B32 Specification for Solder Metal
- D. ASTM B75 Seamless Copper Tube
- E. ASTM D1693 Environmental Stress-Cracking of Ethylene Plastics
- F. ASTM D 635 Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
- G. Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
- H. AMCA 500-D Laboratory Method of Testing Dampers for Rating

### **1.04 SUBMITTALS**

- A. The following sections shall be submitted together as one package and shall be referenced on submittal cover page and paperwork.
  1. 23 09 15
  2. 23 09 54
  3. 23 09 93
- B. The following shall be included:
  1. Building Automation System Network Architecture Diagram indicating network layout of all communication buses including all hardware, operator workstation and software, and integrated devices. Where multiple field-level controllers are installed (e.g. VAV Box controller), references made to "typical of #" are acceptable.
  2. Manufacturer's data sheets indicating model number, pressure/temperature ratings, capacity, methods and materials of construction, installation instructions, and recommended maintenance. General catalog sheets showing a series of the same device is not acceptable unless the specific model is clearly marked.

3. Schematic flow diagrams of systems showing fans, pumps, coils, dampers, valves, and other control devices. Each control device provided under this section shall be uniquely labeled. Duplicate labeling may be used within similar mechanical systems. Label each device with setting or adjustable range of control. Indicate all wiring, clearly, differentiating between factory and field installed wiring. Wiring should be shown in schematics that detail contact states, relay references, etc. Diagrammatic representations of devices alone are not acceptable.
4. Details of construction, layout, and location of each temperature control panel within the building, including instruments location in panel and labeling. Also include on drawings location of mechanical equipment controlled (room number), locations of all remote sensors and control devices (either by room number or column lines).
5. A list of all inputs and outputs associated with each controller.
6. Bill of Materials for all controls devices provided on the project, indicating part numbers, device manufacturer, and description of part.
7. Schedule of control dampers indicating size, leakage rating, arrangement, pressure drop at design airflow, and number and size of operators required.
8. Schedule of control valves indicating system in which the device is to be used, rated capacity, flow coefficient, flow required by device served, actual pressure drop at design flow, size of operator required, close-off pressure, and locations where valves are to be installed.
9. Sequence of operations for all DDC equipment.
10. All submittals are to comply with submission and content requirements specified in applicable provisions of Division 1.

#### **1.05 QUALITY ASSURANCE**

- A. Installer: Installing contractor must be a manufacturer's branch office or an authorized representative of a Direct Digital Control (DDC) equipment manufacturer that provides engineering and commissioning of the DDC equipment. DDC equipment may or may not be required to be installed by this contractor as part of the project, but the intent of this quality assurance specification is to ensure that the installing contractor has the capabilities to engineer, install, and commission the field devices supplied under this section for temperature control. Installer response time during the warrantee period shall be four (4) hours or less (24 hours/day, 7 days/week).
- B. Electrical Standards: Provide electrical products that have been tested, listed and labeled by Underwriters' Laboratories (UL) and comply with NEMA standards.
- C. Provide control devices subject to corrosive environments with corrosion protection or construct them so they are suitable for use in such an environment.

- D. Provide devices exposed to outside ambient conditions with weather protection or construct them so they are suitable for outdoor installation.

#### **1.06 DELIVERY, STORAGE, AND HANDLING**

- A. Provide factory shipping cartons for each piece of equipment and control device. Provide factory applied plastic end caps on each length of pipe and tube. Maintain cartons and end caps through shipping, storage and handling as required to prevent equipment and pipe end damage and to eliminate dirt and moisture from equipment and inside of pipe and tube. Store equipment and materials inside and protected from weather.

#### **1.07 OPERATION AND MAINTENANCE DATA**

- A. The following sections shall be submitted together as one package for O&M Data: 23 09 15, 23 09 54, and 23 09 93. Specification sections shall be referenced on O&M submittal cover page and paperwork. Controls drawing package (as described below) shall clearly reference "As-built" or "Record Drawings" on title sheets with appropriate date. Simply submitting a copy of the original submittal with original submittal date in lieu of providing what is described herein is not acceptable and will be rejected. Include the following information:
  - 1. As-built Building Automation System Network Architecture Diagram indicating network layout of all communication buses including all hardware, operator workstation and software, and integrated devices.
  - 2. As-built communication bus routing of all connected devices. Each DDC controller shall be indicated and clearly shown which communication bus it resides on and the order of devices along the communication bus. Indicate where "End Of Line" is.
  - 3. Manufacturer's data sheets indicating model number, pressure/temperature ratings, capacity, methods and materials of construction, installation instructions, and recommended maintenance. General catalog sheets showing a series of the same device is not acceptable unless the specific model is clearly marked.
  - 4. As-built list of all inputs and outputs associated with each controller.
  - 5. As-built Bill of Materials for all controls devices provided on the project, indicating part numbers, device manufacturer, and description of part.
  - 6. As-built schematic flow diagrams of systems showing fans, pumps, coils, dampers, valves, and other control devices. Each control device provided under this section shall be uniquely labeled. Duplicate labeling may be used within similar mechanical systems. Label each device with setting or adjustable range of control. Indicate all wiring, clearly, differentiating between factory and field installed wiring. Wiring should be shown in schematics that detail contact states, relay references, etc. Diagrammatic representations of devices alone are not acceptable.

7. As-built details of construction, layout, and location of each temperature control panel within the building, including instruments location in panel and labeling. Also include on drawings location of mechanical equipment controlled (room number), locations of all remote sensors and control devices (either by room number or column lines).
8. As-built schedule of control dampers indicating size, leakage rating, arrangement, pressure drop at design airflow, and number and size of operators required.
9. As-built schedule of control valves indicating system in which the device is to be used, rated capacity, flow coefficient, flow required by device served, actual pressure drop at design flow, size of operator required, close-off pressure, and locations where valves are to be installed.
10. As-built sequence of operations for all DDC equipment, including final setpoints established with balancing contractor.
11. Completed Functional Performance Testing forms, as detailed in Section 23 08 00.

#### **1.08 AGENCY TRAINING**

- A. At project close-out, contractor to provide factory authorized representative and/or field personnel knowledgeable with the operations, maintenance and troubleshooting of the system and/or components defined within this section.
- B. Unless otherwise directed by Agency DDC operations personnel, training provided by contractor shall include the following topics:
  1. OPERATOR INTERFACE TASKS, demonstrating how to:
    - a. Login/Logout
    - b. Define and modify schedules for equipment operation
    - c. View point data in lists and on graphics
    - d. View live trend data
    - e. View historical trend data
    - f. Acknowledge alarms
    - g. Adjust setpoints
    - h. Manually override logic and force actions, and release back to auto control
    - i. Edit time schedule parameters
  2. WALKING TOUR OF DDC SYSTEM:
    - a. Locations of all controlled HVAC systems (excluding terminal units unless in obscure location)
    - b. Locations of all Temperature Control Panels and designated function
    - c. Locations of any system sensors or controlled devices located outside of mechanical or electrical rooms (e.g. outdoor air temperature sensor, outdoor air static pressure reference, water differential pressure sensors, AHU supply static sensor, emergency HVAC shutdown switch)

3. TRAINING REFERENCE MATERIAL: At the time of owner training, provide a binder to the building operator containing the following information:
  - a. Simple step-by-step instructions, in a clear format, outlining the most commonly executed operator interface tasks as listed above. In lieu of printed material, contractor may provide instructional video demonstrating the tasks.
  - b. A copy of the DDC completed as-built drawings as defined above in "OPERATION AND MAINTENANCE DATA".
  - c. In each temperature control panel, provide a copy of the control drawings that pertain to equipment served by the temperature control panel. This should include a flow schematic of the system(s) served, the control panel and field wiring diagrams, and the sequence of operations.
  - d. Provide two follow-up visits for troubleshooting and instruction, one six months after substantial completion and the other at the end of the warranty period. Length of each visit to be not less than 4 hours or the time necessary to provide required information and complete troubleshooting and inspection activity for all controls installed. Coordinate the visit with the owner/Agency and provide an inspection report to the owner of any deficiencies found.

## **PART 2 PRODUCTS**

### **2.01 MATERIALS AND EQUIPMENT**

#### **A. General:**

1. Provide electric temperature control products in sizes and of capacities as required, conforming to manufacturer's standard materials and components as published in their product information; designed and constructed as recommended by manufacturer and as required for application indicated.
2. Provide control devices subject to corrosive environments with corrosion protection or construct them so they are suitable for use in such an environment.
3. Provide devices exposed to outside ambient conditions with weather protection or construct them so they are suitable for outdoor installation.
4. Use only UL labeled products that comply with NEMA Standards. Electrical components and installation to meet all requirements of the electrical sections (Division 26) of project specifications.
5. All valve and damper operators shall fail safe upon control power failure where indicated with a "NO" or "NC" on the HVAC controls schematics in the plans.

#### **B. Control Valves:**

1. Provide all control valves as shown on the plans/details and as required to perform functions specified.

2. Size operators to allow smooth and positive operation of devices served and to provide sufficient torque capacity for tight shutoff against system temperatures and pressure encountered.
3. For electric modulating actuation, use fully proportional actuators with 0-10VDC inputs unless specified otherwise in the chart below. For two-position electric actuation use 24 VAC for DDC controlled actuators, 120 VAC actuators may be used for hardwire interlocking. Electric actuators, for applications other than terminal units, shall be provided with a manual override capability. All electric actuators shall be provided with a visible position indicator.
4. Provide operators that are full proportioning or two-position, as required for specified sequence of operation. Provide spring-return for applications involving fire, freeze protection, moisture protection or specified normally open/closed operation. Valves shall move to their fail positions on loss of electrical power.
5. Two-position shut-off valves used for isolation of mechanical devices shall be sized for a maximum pressure drop of 2 PSI at design flow and shall be a minimum of line size.
6. Valve selections shall conform with the following table:

| <b>VALVE<br/>SERVING</b>      | <b>TYPE</b><br>Globe,<br>Butterfly<br>(BF), Ball,<br>Press<br>Independent<br>Ball (PI Ball) | <b>SIGNAL</b><br>0-10 VDC<br>TriState<br>(24VAC)<br>2-Position<br>Elect | <b>SPRING<br/>RETURN<br/>REQUIRED</b><br>Yes<br>No | <b>FAIL<br/>POSITION</b><br>Open (thru<br>Coil)<br>Closed (bypass<br>Coil)<br>Last Position |
|-------------------------------|---------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------------------|
| Reheat Coil                   | Globe or<br>Ball                                                                            | 0-10 VDC                                                                | No                                                 | Last Position                                                                               |
| Radiation w/<br>Reheat        | Globe or<br>Ball                                                                            | 0-10VDC,<br>TriState,<br>or 2-Pos                                       | No                                                 | Last Position                                                                               |
| Standalone<br>Radiation       | Globe or<br>Ball                                                                            | 0-10 VDC<br>or<br>TriState                                              | No                                                 | Last Position                                                                               |
| CUH and UH                    | Globe or<br>Ball                                                                            | TriState<br>or 2-Pos                                                    | Yes                                                | Open                                                                                        |
| Fan Coil Heating              | Globe or<br>Ball                                                                            | 0-10 VDC                                                                | Yes                                                | Open                                                                                        |
| Fan Coil Cooling              | Globe or<br>Ball                                                                            | 0-10 VDC                                                                | Yes                                                | Closed                                                                                      |
| AHU Hot Water<br>Heating Coil | Globe or<br>Ball                                                                            | 0-10 VDC                                                                | Yes                                                | Open                                                                                        |
| AHU Cooling Coil              | Globe, Ball,<br>or BF (BF<br>only when<br>3" or                                             | 0-10 VDC                                                                | Yes                                                | Closed                                                                                      |

| <b>VALVE<br/>SERVING</b> | <b>TYPE</b><br>Globe,<br>Butterfly<br>(BF), Ball,<br>Press<br>Independent<br>Ball (PI Ball)<br>greater) | <b>SIGNAL</b><br>0-10 VDC<br>TriState<br>(24VAC)<br>2-Position<br>Elect | <b>SPRING<br/>RETURN<br/>REQUIRED</b><br>Yes<br>No | <b>FAIL<br/>POSITION</b><br>Open (thru<br>Coil)<br>Closed (bypass<br>Coil)<br>Last Position |
|--------------------------|---------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------------------|
|                          |                                                                                                         |                                                                         |                                                    |                                                                                             |

C. Control Valves in Water Systems:

1. Use equal percentage valves for two-way control valves serving coils. Use linear valves for two-way control valves meant to satisfy flow conditions (e.g. chiller minimum flow valve, boiler minimum flow valve, chiller heat recovery flow valve). Consult with AE for acceptable pressure drop if available valve selections do not fall within the desired pressure range. Note: For low flows, the required minimum Cv size will result in lower pressure drop than 4 psi.
2. Use three-way valves sized for a maximum pressure drop of 5 psi and that have linear characteristics so that the valve pressure drop remains constant regardless of the valve position.
3. Globe valves 2" and smaller: Cast bronze or forged brass body, brass plug and brass or stainless steel seat, stainless steel stem, screwed ends, suitable for use on water systems at 150 psig and 240° F. Seat leakage with actuator supplied will meet ANSI class IV leakage (0.01%). For globe valves that are specified to fail in place, valves shall be open when the stem is up. Only the following globe valve body styles will be acceptable for terminal unit control: Siemens Powermite 599 VF Series (599 VE Series Zone Valves are not acceptable), Invensys VB7200 Series, Johnson Controls VG7000 Series, and Honeywell V5011/V5013 Series. Minimum size for globe valves shall be 1.5 Cv. No minimum size for CCV ball valves.
4. Globe valves 2 1/2" and larger: Iron body, brass plug and seat, stainless steel stem, spring loaded Teflon, or EPDM packing, flanged ends, suitable for use on water systems at 150 psig and 240° F.
5. Butterfly valves: Iron body, stainless steel shaft, bronze bearings, and resilient seat. Disc to be aluminum-bronze, nickel-plated ductile iron, cast iron with welded nickel edge, Nylon 11 coated, or stainless steel. Valve assembly to be bubble tight, suitable for use on water systems at 150 psig and 240° F. For pneumatically actuated valves, provide pilot positioners on all operators for butterfly valves used in modulating applications. When butterfly valves are used in modulating applications, entering and leaving pipe sizes and required transition distances shall be detailed on the control valve submittals. The control contractor shall be responsible for coordinating the proper pipe sizes and transitions with the mechanical contractor to provide the correct Cv at 70° open position.

6. Characterized Ball Valves: The following manufacturers are acceptable: Honeywell, Belimo, Johnson Controls, KMC Controls, Yamatake, Bray. For use on terminal units only where specified above. Forged brass or bronze body, stainless steel shaft and ball, reinforced Teflon or PTFE ball seals, double O-ring stem seals, characterized disk, maximum of ANSI Class IV (0.01%) leakage, suitable for use on water systems at 150 psig and 212° F. Note: Only ball valves with a characterized disc shall be acceptable.

D. Control Dampers:

1. Provide control dampers shown on the plans and as required to perform the specified functions. Dampers shall be rated for velocities that will be encountered at maximum system design and rated for pressure equal or greater than the ductwork pressure class as specified in [Section 23 31 00] of the ductwork where the damper is installed.
2. Use only factory fabricated dampers with mechanically captured replaceable resilient blade seals, stainless steel jamb seals and with entire assembly suitable for the maximum temperature and air velocities encountered in the system.
3. All dampers in stainless steel, PCD coated steel, PVC, PTFE, or fiberglass ductwork shall be constructed of stainless steel.
4. All dampers in aluminum ductwork shall be constructed of stainless steel or aluminum.
5. Dampers in galvanized ductwork shall be constructed of galvanized steel and/or aluminum.
6. All dampers, unless otherwise specified, to be rated at a minimum of 180° F working temperature. Leakage testing shall be certified to be based on latest edition of AMCA Standard 500-D and all dampers, unless otherwise specified, shall have leakage ratings as follows:

|          |          |                  |                         |                                  |                |
|----------|----------|------------------|-------------------------|----------------------------------|----------------|
| Class IA | 1" w.g.  | =/<3<br>CFM/ft2  | <b>Damper<br/>Class</b> | <b>Differential<br/>Pressure</b> | <b>Leakage</b> |
| Class I  | 4" w.g.  | =/<8<br>CFM/ft2  |                         |                                  |                |
| Class I  | 8" w.g.  | =/<11<br>CFM/ft2 |                         |                                  |                |
| Class I  | 12" w.g. | =/<14<br>CFM/ft2 |                         |                                  |                |

7. Leakage rate dampers for differential pressures that they will encounter at maximum system design pressures.
8. Steel framed dampers: Nailor models 2010 & 2020; Greenheck models VCD-33 & VCD-42; Johnson Controls model V-1330; Ruskin Models CD60 & CD40; other approved equal.
9. Aluminum frame and blade dampers: Nailor models 2010EAF & 202EAF; Greenheck model VCD-43; Ruskin model CD50; Arrow model AFD-20; other approved equal.

10. Dampers used for directed mixing of airstreams, i.e. outside air and return air, to be parallel blade type and sized for an air velocity of 1800 to 2000 fpm with the damper blades shall be arranged so that the air streams are directed at one another to facilitate mixing. Dampers used for throttling or modulating applications other than air stream mixing to be opposed blade type. Two position dampers may be parallel or opposed blade type.
  11. Dampers used for isolation on the discharge of centrifugal fans shall have damper blades perpendicular to the fan shaft to minimize system effect. Dampers mounted with blades vertically shall be designed for vertical blade orientation.
  12. Dampers for applications other than fume exhaust to have frames of not less than 16 gauge galvanized steel or 12 gauge extruded aluminum. Blades to be two-ply steel airfoil of not less than 2 x 20 gauge galvanized steel (14 gauge equivalent) or extruded aluminum airfoil, with stainless steel, acetal, Celcon, bronze, or nylon bearings. Maximum allowable blade width is 8 inches. Use plated steel linkage hardware.
  13. Maximum damper width is 48 inches; where required width exceeds 48 inches, use multiple damper sections. Inside frame free area shall be a minimum of 90% of total inside duct area.
  14. Multiple width damper sections shall utilize jack shaft linkages unless noted below.  
Sections over 144 inches wide shall be actuated from two locations on the jack shaft.  
Double width damper sections for two-position operation may be actuated without jack shafts if each damper section is actuated separately. Dampers that have multiple width and multiple vertical sections shall have a jackshaft for each vertically stacked set of dampers and be provided with crossover linkages between jack shafts to transfer uneven loading.
  15. Jack shafts shall be extended outside of the ductwork for external actuator mounting. Provide bearings on the point of exit for support of damper shafts to prevent wear on the shaft and the ductwork. If locating actuators out of the air stream is impossible, obtain mounting location approval from the designer unless the contract documents indicate in air stream mounting is acceptable. In no cases shall damper actuators for fume exhaust systems be located in the air stream or require entering the air stream to service an actuator.
- E. Electric Operators:
1. Provide weatherproof NEMA 4 enclosures that have removable covers that have clasps or machine screws (no sheet metal screws) and that do not require removing fasteners from the ductwork to prevent actuator failure or freeze-up when mounting in locations exposed to harsh environments or outdoor locations.

2. Size operators for smooth and positive operation of devices served, and with sufficient torque capacity to provide tight shutoff against system temperatures and pressure encountered. For electric modulating actuation, use fully proportional actuators with zero and span adjustments. For two-position electric actuation use 24 VAC for DDC controlled actuators, 120 VAC actuators may be used for hardwire interlocking.
  3. Actuator stroke times shall match the requirements of the DDC controllers provided under 23 09 23 and/or the specific system requirements for proper operation. All electric actuators will be provided with overload protection to prevent motor from damage when stall condition is encountered. Equip operators with spring return or stored energy fail-safe return for applications involving fire, freeze protection, moisture protection or specified normally open/closed operation. Face and bypass dampers for heating applications shall fail to the face position.
  4. Provide independently mounted damper end switches (Kele TS-475, Ruskin SP-101/105, or equal) with form "C" contacts where control sequences require damper position indication or interlock. Damper end switches shall be independent of the damper actuators and be mounted directly to the damper shaft or auxiliary shaft that is mounted to a drive blade of the damper. End switches shall not contain mercury.
  5. All power required for electric actuation shall be provided by this contractor if it is not able to be directly provided from the DDC controller.
  6. Provide operators with linkages and brackets for mounting on device served.
- F. Electric/Electronic Thermostats (Stand-alone operation where points not specified in 23 09 15):
1. Electric Thermostats:
    - a. For single setpoint applications, provide line or low voltage electric type suitable for heating or heating and cooling as required.
  2. Low Voltage Electronic Thermostats:
    - a. Where unoccupied setpoints are specified, provide electronic programmable type with seven-day setup/setback scheduling with setpoints and occupancy times as indicated in 23 09 93. For heating and cooling applications, provide automatic heating/cooling switchover. For applications that control fans, provide fan override switch. For ventilation or packaged economizer applications provide a dry contact for ventilation damper or economizer initiation. For thermostat control of economizer, provide a 0-10VDC modulated output for economizer damper control.
    - b. For applications that require integration to the building automation system, provide a BACnet communication interface. If a communication interface is specified, occupancy scheduling in the thermostat is not required.
  3. Low Limit Thermostats (Freezestats):

- a. Electric two-position type with temperature sensing element and manual reset for all applications. Unit to be capable of opening control circuit if any one-foot length of sensing element is subject to a temperature below the setpoint. Length of sensing element to be not less than one lineal foot per square foot of coil surface areas.  
Unless otherwise indicated, set low limit controls at 36°F.
- 4. Aquastats:
  - a. Line voltage type with single pole, double throw switch of adequate rating for the applied load.
- G. Electronic Temperature Sensors/Transmitters:
  - 1. Thermistor temperature sensor manufacturers: PreCon, BAPI, Veris, JCI, and ACI
  - 2. Use thermistor or RTD type temperature sensing elements constructed so accuracy and life expectancy is not affected by moisture, physical vibration, or other conditions that exist in each application. RTD's shall be of nickel or platinum construction and have a base resistance of 1000 ohm at 70°F and 32°F respectively. 100 ohm platinum RTD's are acceptable if used with temperature transmitters.
  - 3. The temperature sensing device used must be compatible with the DDC controllers used on the project.
    - a. RTD
      - 1) Accuracy (Room Sensor Only): minimum + 1.0°F
      - 2) Accuracy (Averaging): minimum + 1.2°F
      - 3) Accuracy (Other than Room Sensor or Averaging): minimum + 0.65°F
      - 4) Range: minimum -40 - 220°F
    - b. Thermistor
      - 1) Accuracy (All): minimum + 0.36°F
      - 2) Range: minimum -30 - 230°F
      - 3) Heat Dissipation Constant : minimum 2.7 mW/°C
    - c. Temperature Transmitter
      - 1) Accuracy: minimum + 0.1°F or +0.2% of span
      - 2) Output: 4-20 mA
  - 4. Provide limited range or extended range sensors if required to sense the range expected for a respective point. Use RTD type sensors for extended ranges beyond -30 to 230°F. If RTD's are incompatible with DDC controller direct temperature input use temperature transmitters in conjunction with RTD's.

5. Use wire size appropriate to limit temperature offset due to wire resistance to 1.0°F. If offset is greater than 1.0°F due to wire resistance, use temperature transmitter. If feature is available in DDC controller, compensate for wire resistance in software input definition.
  6. Zone temperature sensors shall be provided with digital displays that indicate room temperature and setpoint and have a manual occupancy override where indicated in 23 09 15 DDC Points List. Provide setpoint adjustment as specified in the DDC Input/Output Summary Table and sequence of operation.
  7. Use averaging elements on duct sensors when the ductwork is ten square feet or larger. All mixed air and heating coil discharge sensors shall have averaging elements regardless of duct size.
  8. In piping systems use temperature sensors with separable wells designed to be used with temperature element.
- H. Humidity Sensors:
1. Use capacitive thin-film polymer sensor types with a range of 0-100% RH. Accuracy to be no less than  $\pm 2\%$  in the range of 20% RH to 80% RH with a response time of 120 seconds or less. Provide covers for room humidity sensors as specified for temperature sensors.
  2. For outside air applications, use sensor designed for outside air use along with weather enclosure. Provide sensor equal to Vaisala Model HMD60UO w/ DTR503B enclosure and weather resistant mounting hardware.
- I. Pressure Transducers (Air):
1. Provide pressure transducers specified below for the following applications:
    - a. Duct static pressure applications where setpoints are specified to control at greater than 0.1" w.c.
    - b. Pitot type fan inlet air flow stations.
  2. Manufacturers: Mamac Systems, Setra, and Veris Industries.
  3. Provide a transmitter that operates on the capacitance principle and is capable of sensing low positive, negative or differential pressures. Transmitter shall have a minimum of three pressure ranges adjustable by an onboard switch or jumper. Size the transmitter where the middle or high range is suitable for the application. Use a bi-directional transmitter for applications that may have both positive and negative pressure excursions. Transmitter shall be provided with an integral four-digit display of the pressure sensed.
    - a. Accuracy (including non-linearity and hysteresis): + 1% FS
    - b. Compensated Temperature Range: 32°-140° F
    - c. Temperature Effect: 0-1"wc Range .09% FS/°F; >1"wc Range .02% FS/°F
    - d. Output: 4-20 MA
    - e. Load Impedance (smallest maximum acceptable): 800 ohm max.

- f. Operating Temperature: 32°-140° F
- 4. Provide pressure transducers specified below for the following applications:
  - a. Duct static pressure applications where setpoints are specified to control at 0.1" w.c. or lower.
  - b. All duct mounted pitot type air flow stations.
  - c. Space/building static control or monitoring.
- 5. Manufacturers: Setra 267, Paragon Controls MicroTrans, Air Monitor Veltron DPT2500 Plus, or approved equal. The airflow transducer shall provide zero and span adjustment for calibration. Use a bi-directional transmitter for applications that may have both positive and negative pressure excursions. Transmitter shall be provided with an integral four-digit display of the pressure sensed.
  - a. Transducer Span: <2 times the design velocity pressure at maximum flow, single range
  - b. Accuracy: +/-0.25% of full scale, including non-linearity, hysteresis, deadband, and non-repeatability
  - c. Temperature Effect: +/-0.15% of full scale/°F
  - d. Response: 0.5 sec. for 98% of full span change
  - e. Overpressure: 5 PSIG Proof
  - f. Power: 24VAC/VDC
  - g. Analog Output: 0-5VDC, 0-10VDC, or 4-20mA field adjustable
- 6. For space or building static pressure monitoring, use Vaisala model SPH10 Static Pressure Head, or approved equal for outside air reference. Mount in location above roofline away from any air exchanges.
- J. Pressure Transducers (Liquid/Steam):
  - 1. Differential Pressure Transducers utilized for measuring flow across each chiller shall have an accuracy of +/-0.2%. All other criteria shall be met as detailed below.
  - 2. Provide a transmitter that utilizes capacitive or thin film strain gauge sensing. Provide for an analog gauge piped in parallel with the transducer. Gauge shall meet specifications as specified in Section 23 05 15. Coordinate with mechanical contractor to provide and install this gauge. For differential pressure applications provide with bypass valve manifold assembly with valved venting capability.
    - a. Accuracy (including non-linearity and hysteresis): + 0.5% FS
    - b. Compensated Temperature Range: 32°-150° F
    - c. Temperature Effect (over compensated range): 0.03%/°F;
    - d. Output: 4-20 MA
    - e. Load Impedance (smallest maximum acceptable): 600 ohm Minimum
    - f. Operating Temperature: 0°-175° F

g. Hysteresis: 0.75% of span

K. Differential Pressure Switches:

1. Differential pressure switches shall sense both inlet and outlet of pressure across a component. Device shall be rated for 150% of maximum system pressures that may be encountered. Provide with pressure differential that will be required to meet specified operation and/or to prevent nuisance "toggling" of the device in the system served.

L. Air Pressure Safety Switches:

1. Air pressure safety switches shall be a differential pressure switch that will sense differential, negative, or positive pressure as required by the sequence of operation specification. Device shall be rated for a minimum of 150% of maximum system pressures that may be encountered. Provide with pressure range that will be required to meet specified operation in the system served. Provide with a normally closed contact that will open above setpoint and will not close until the manual reset button is depressed. Setpoint shall be manually adjustable.

M. Current Status Switches:

1. Provide a current sensor with adjustable threshold and digital output with LED display, equal to a Veris model H-708/H-904. Threshold adjustment must be by a multi-turn potentiometer or set by multiprocessor that will automatically compensate for frequency and amperage changes associated with variable frequency drives. When used on variable speed motor applications, use a current sensor that will not change state due to varying speeds.

N. Carbon Dioxide (CO2) Sensor:

1. For rooms where a CO2 sensor and temperature sensor are both required, provide a combination device such that one wall sensor measures both temperature and CO2.
2. Provide a Carbon Dioxide (CO2) sensor that shall utilize non-dispersive infrared (NDIR) technology. The sensor shall have a linear analog output over a range of 0-2000 ppm and have built in display of CO2 level. The sensor shall have an automatic calibration algorithm that will compensate for sensor drift over time due to sensor element degradation. Unit shall be provided with a 0-10VDC or 4-20mA analog output that is selectable and a field adjustable relay alarm output. Accuracy shall be better than  $\pm 5\%$  of reading or  $\pm 50$ ppm whichever is higher.
3. The sensor shall be user calibratable with a minimum calibration interval of five years.

O. Airflow Measuring Stations:

1. Provide airflow measuring stations (AMS) for ducts, fan inlets, and outside air as required on plans.
2. Acceptable Manufacturers: Accutrol IAQ-TEK for outside airflow measurement, where scheduled.

3. Substitution Requirements:
  - a. For any product to be considered for substitution, a written document shall be submitted to the engineer detailing exceptions and compliance, section-by-section with supporting documentation, before an approval will be considered
  - b. Any product submitted as an equal shall be expected to comply with all performance capabilities and functional aspects of this specification.
4. Excluded Devices:
  - a. Measurement technologies such as Thermal Dispersion type using multipoint “bead-in-glass” thermistors are not acceptable.
  - b. Measurement technologies such as Thermal Dispersion type using “chip-in-glass”, “chip-in-epoxy” or “chip” type thermistors for the heated sensor component are not acceptable.
  - c. Transmitter and probe assemblies that state factory recalibration is required to maintain accuracy are not acceptable.
  - d. Airflow sensors that are affected by dust, humidity and altitude are not acceptable.
5. Airflow measuring stations for ducts:
  - a. General
    - 1) Provide AMS location as shown on the plans, schedules and/or control diagrams to determine the average airflow rate for monitoring and/or control.
    - 2) Each VorTek AMS shall be provided with a microprocessor-based transmitter and one or more sensors.
    - 3) Airflow measurement device shall be field configurable and adjustable to determine the average airflow rates.
  - b. Transmitter:
    - 1) The transmitter shall be capable of utilizing a remote display when the location of the transmitter is not accessible, connected with factory assembled cables that are available in lengths of 25', 50', 75' and 100' as required for remote digital readout locations.
    - 2) The measurement input shall be digital and will not require an Analog-to-Digital convertor. The transmitter shall provide a scalable analog output, which is field configurable using a free intuitive graphical user interface. The output signal of the transmitter shall be 0-10VDC. Power requirement for the transmitter shall be 24VAC or DC.
    - 3) Measurement system accuracy shall be +/- 3% of volumetric airflow rate with recommended sensor density, installation distribution and proper upstream requirements. Individual sensor accuracy shall be +/- 2% of reading to NIST-traceable standards. Measurement system accuracy of duct airflow measurement shall be +/-3% of volumetric airflow rate; +/-5% of reading for fan inlet and fan array systems.

- 4) Configuration parameters and adjustments shall be accessible via a free Graphical User interface (GUI) PC application that connects to the transmitter locally, or through the remote display via a standard USB Mini B port. This GUI application shall be available to the technician or the balancer via a free download, thereby reducing start-up and commissioning time without dependence on factory trained personnel to be onsite for this work. Menu driven interfaces using push button and simple alpha numeric display are not acceptable.
  - 5) The transmitter shall have the ability through the GUI, to provide a simple calculator for the balancer's field adjustment.
  - 6) The transmitter shall be CE Marked and RoHS compliant.
- c. IAQ-TEK for Outdoor Air:
- 1) General:
    - a) Provide IAQ-TEK measurement location as shown on the plans, schedules and/or control diagrams to determine the average airflow rate for monitoring and/or control of Outside Air.
    - b) Each IAQ-TEK shall be provided with a microprocessor-based transmitter and one or more sensor probes.
    - c) Airflow measurement shall be field configurable and adjustable to determine the average airflow rates.
    - d) Each IAQ-TEK measurement location shall be comprised of a set of probes to properly sample the air intake.
  - 2) Velocity Sensing Probes:
    - a) Velocity Range: Probe shall operate over the range of 1000 to 75 fpm with a 0.100"wc transmitter, higher range transmitters shall be available for greater velocities. Turndown in any specific application shall be a minimum of eight to one.
    - b) Quantity: Probes are to be provided in the quantity recommended by the manufacturer for the specific area to be monitored.
    - c) Mounting: Probes shall be provided with any special hardware required to assure secure mounting. Mounting hardware shall be 304SS. Galvanized or aluminum hardware shall be unacceptable. Probe shall be mounted to minimize extreme angular velocities. Installer to follow manufacturer's mounting instructions.
    - d) Orientation: Probe must be located facing into air stream and isolated from return airflow. Pressure connection barbs must be upright.

- e) Cleaning: Probes shall be able to withstand periodic wash-down with water without a degradation in signal quality. If probes cannot be cleaned in this manner, provide upstream filter assemblies to protect the probes from dirt. Filters shall be provided upstream due to contaminants in outside air.
  - f) Humidity: Sensor shall not be affected by high levels of water vapor, including entrained rain and fog. Thermal devices shall not be acceptable due to condensation affecting the operation of the unit.
- 3) Transducer:
- a) Style: Differential pressure type, high accuracy, complete with auto-zero valve and ambient temperature sensor.
  - b) Range: Differential pressure range shall be selected for the corresponding air velocity range being measured.
  - c) Temperature range: Transducer shall be capable of operating over the range of -30 to 120 degrees F without any temperature induced errors including zero or span shift.
  - d) Environment: Transducer shall be mounted in a sealed NEMA 4 enclosure, suitable for mounting in the outdoor air plenum.
  - e) Pressure Connections: 1/4 inch barbed connections shall be provided for high and low pressure sensing.
  - f) Electrical Connections: A weather tight connection cable with weatherproof Amphenol type connector shall be provided. Cable shall be plenum rated.
  - g) Humidity: Transducer shall be protected from condensation in sensing chamber and connection tubing when transducer temperature is lower than the dew point of the measured air stream.
- 4) Monitor Electronics:
- a) Style: Microprocessor based electronics including integral display and operator keypad.
  - b) Function: Receive signals from transducer and probes, calculate outdoor air volume and temperature, display information to user, transmit information to building automation system, perform self-diagnostics, and alarm on low outdoor air volume.
  - c) Display: A 4-line by 20-character alpha-numeric LCD operator's display shall be provided and shall be backlit for use in low light areas.
  - d) Temperature range: Monitor shall be capable of operating over the range of +30 to 110 degrees F.

- e) Environment: Monitor shall be mounted in a sealed NEMA 4 enclosure, suitable for mounting outdoors if required. Enclosure shall include clear window to allow viewing of monitor display without opening the door.
- f) Calculations: Monitor shall perform calculations including: differential pressure to velocity and velocity to volume conversions; and, correct for altitude, intake air temperature, transducer zero drift and span shift.
- g) Analog Outputs: Monitor shall provide industry standard 4-20mA outputs for corrected volume and outdoor air temperature. Scaling of volume output shall be adjustable by the user. Diagnostic functions shall be provided to assist in troubleshooting connections.
- h) Contact Outputs: A SPDT contact shall be available which will be normally energized and shall indicate either an alarm condition or unit problem.
- i) Setup Wizards: The monitor shall include preprogrammed setup wizards to lead the building automation contractor, test and balance contractor, and/or user through the steps necessary to commission the system.

P. Temperature Control Panels:

- 1. Constructed of steel or extruded aluminum, with hinged door, keyed lock, and baked enamel finish. Install controls, relays, transducers and automatic switches inside panels. Label devices with permanent printed labels and provide asbuilt wiring/piping diagram within enclosure. Provide raceways for wiring and poly within panel for neat appearance. Provide termination blocks for all wiring terminations. Label outside of panel with panel number corresponding to plan tags and asbuilt control drawings as well as building system(s) served.
- 2. Control panels that have devices or terminations that are fed or switch 50V or higher shall enclose the devices, terminations, and wiring so that Personal Protective Equipment (PPE) is not required to service the under 50V devices and terminations within the control panel. As an alternative, a separate panel for only the 50V and higher devices may be provided and mounted adjacent to the under 50V control panel.
- 3. Provide a disconnect switch inside the temperature control panel that interrupts power to all powered devices inside the panel as well as field devices powered from the panel.

Q. Power Supplies:

- 1. Provide all required power supplies for actuators, transducers, sensors, transmitters and relays. All low voltage transformers shall have a resettable secondary circuit breaker and be listed as class 2 power supplies.

### **PART 3 EXECUTION**

#### **3.01 INSTALLATION**

- A. Install system with trained mechanics and electricians employed by the control equipment manufacturer or an authorized representative of the manufacturer. Where installing contractor is an authorized representative of the control manufacturer, such authorization shall have been in effect for a period of no less than three years.
- B. Install all control equipment, accessories, wiring, and piping in a neat and workmanlike manner. All control devices must be installed in accessible locations. This contractor shall verify that all control devices furnished under this Section are functional and operating the mechanical equipment as specified in Section 23 09 93.
- C. Label all control devices with the exception of terminal unit devices with permanent printed labels that correspond to control drawings. Labeling for each device shall be unique within each mechanical system.
- D. All control devices and electrical boxes mounted on insulated ductwork shall be mounted over the insulation. Provide mounting stand-offs where necessary for adequate support. Cutting and removal of insulation to mount devices directly on ductwork is not acceptable. This contractor shall coordinate with the insulation contractor to provide for continuous insulation of ductwork.
- E. Mounting of electrical or electronic devices shall be protected from weather if the building is not completely enclosed. This Contractor shall be solely responsible for replacing any equipment that is damaged by water that infiltrates the building if equipment is installed prior to the building being enclosed.
- F. Provide all electrical relays and wiring, line and low voltage, for control systems, devices and components. Install all high voltage and low voltage wiring (includes low voltage cable) in Electrical Metallic Tubing (EMT) except above accessible ceilings. All raceways, enclosures, fittings and associated supports shall be provided and installed according to the requirements set forth in Division 26, NFPA 90 (NEC), Chapter SPS 316 of the Wisconsin Administrative Code. All conduits shall be routed parallel and/or perpendicular to walls and adjacent piping. Raceways shall be located to maintain headroom and working clearance around equipment and devices that require inspection and service. All cable routed to devices within spaces with exposed finished structure shall be installed in EMT raceway routed to the nearest accessible ceiling cavity and the raceway, junction box, supports, fittings, backbox, junction box cover plates, etc. shall be painted to match the architectural finish color.

- G. In general, support all raceways from the building structure. No component of a raceway system shall be secured to corrugated metal roof deck. Do not impose on the installations of other trades. Securing conduit, rods, straps, hangers, etc. to suspended ceiling components, electrical raceways, plumbing piping, fire protection sprinkler piping, HVAC piping or ductwork, or their associated support systems, will not be accepted.
- H. Conduit shall be a minimum of 1/2 " for low voltage control provided the pipe fill does not exceed 40%.
- I. Where HVAC equipment control panels, or devices, do not provide for the direct connection of conduits, exposed wiring may be extended to complete the final connections, providing it does not exceed 18 inches in length.
- J. Minimum low voltage wiring gauge to be 18 AWG for outputs and 20 AWG for inputs. All low voltage wiring to be stranded. IP Cable shall be CAT6.
- K. Low voltage wiring and data cabling can be run without conduit above accessible lay-in tile ceilings. All wiring and data cabling in mechanical rooms, above inaccessible hard ceilings, exterior locations, and in any exposed areas, and in all other locations shall be in conduit. Wire for wall sensors shall be run in conduit. Wiring for radiation valves shall be run in conduit where routed through walls. Existing raceways for sensors shall be reused to limit exposed conduit on walls.
- L. Where wiring/cabling is installed free-air, installation shall comply with the following:
  - 1. Wiring shall utilize the cable tray wherever possible.
  - 2. Wiring shall run at right angles and be kept clear of other trades work.
  - 3. Wiring shall be supported utilizing "J" or "Bridal-type" steel mounting rings anchored to ceiling concrete, piping supports, walls above ceiling or structural steel beams. Mounting rings shall be of open design (not a closed loop) to allow additional wire to be strung without being threaded through the ring. For mounting rings that do not completely surround the wire, attach the wire to the mounting ring with a strap.
  - 4. At HVAC terminal units only, where the wiring serves a specific device; e.g. controller, actuator, transmitter, etc. associated with the unit, the j-hooks or Bridal rings required to support the wiring, may be secured to the rods or straps that support the ductwork or piping that serves the unit. Wall penetrations shall be sleeved.
  - 5. Supports shall be spaced at a maximum 4-foot interval unless limited by building construction. If wiring "sag" at mid-span exceeds 6-inches; another support shall be used.
  - 6. Wall penetrations shall be sleeved and fire stopped as specified.
  - 7. Wiring shall not be supported from existing cabling, existing tubing, plumbing or steam piping, ductwork, any component of a suspended ceiling, or electrical or communications conduit.
- M. IP Communication Cabling:

1. CAT6
  2. Do not bend cable at radius less than manufacturer's recommended bend radius; for unshielded twisted pair use bend radius of not less than 4 times cable diameter.
  3. Do not over-cinch or crush cables.
  4. Do not exceed manufacturer's recommended cable pull tension.
  5. When installing in conduit, use only lubricants approved by cable manufacturer and do not chafe or damage outer jacket.
  6. Manufacturer approved conduit bushings MUST be in place on every conduit opening that cable will be installed in prior to running the cable. Confirm before cable installation.
- N. Line voltage wiring to control panels shall be served by permanent power – under no circumstances shall a control panel be served from receptacle power.
- O. All wiring in control panels shall be terminated on a terminal strip. Wire nuts are not acceptable. A maximum of two wires shall be terminated under any one terminal.
- P. All pneumatic tubing and electrical wiring are to be permanently tagged or labeled within one inch of terminal strip with a numbering system to correspond with the asbuilt drawing package.
- Q. After completion of installation, test and adjust control equipment. Submit data showing set points and final adjustments of controls.

### **3.02 AIR PIPING**

- A. Mechanically attach tubing to supporting surfaces. Sleeve through concrete surfaces in minimum one-inch sleeves, extended 6 inches above floors and one inch below bottom surface of slabs. Fire stop any open space in the sleeve after the air piping is installed if the sleeve is in a fire rated surface.
- B. Install all polyethylene tubing in conduit as scheduled below unless specified otherwise hereafter. Exposed polyethylene tubing not exceeding 18 inches may be used for connection to an instrument or operator without being installed in conduit. All Conduit to be independently supported, all boxes must be supported, all conduit ends to have bushings for protection of tubing.
- C. Conduit shall be a minimum of 1/2 " for poly tubing provided the pipe fill does not exceed 40%.
- D. Minimum poly tubing size allowed is 1/4" OD. If an instrument has a barbed fitting that will only accept 5/32" tubing, connection to the device can be made with 5/32" tubing that is as short as is practical. Couplings are acceptable in this instance.
- E. Install all exposed piping and conduit parallel to or at right angles to the building structure and support adequately at uniform intervals. Use only tool made bends in copper air pipe.
- F. Where polyethylene tubing is installed free-air, installation shall consider the following:
1. Tubing shall run at right angles and be kept clear of other trades work.

2. Tubing shall be supported utilizing "J-" or "Bridal-type" mounting rings anchored to ceiling concrete, piping supports or structural steel beams. Rings shall be designed to maintain tubing bend to larger than the minimum bend radius (typically 4 x tubing diameter).
  3. Supports shall be spaced at a maximum 4-foot interval unless limited by building construction. If tubing "sag" at mid-span exceeds 6-inches, another support shall be used.
  4. Tubing shall never be laid directly on the ceiling grid or attached in any manner to the ceiling grid wires.
- G. Tubing shall not be attached to existing cabling, existing tubing, plumbing or steam piping, ductwork, ceiling supports or electrical or communications conduit.
- H. Tubing connected to air terminal unit devices shall be attached to the terminal unit device to prevent tubing from becoming kinked or becoming disconnected. Tubing serving air terminals may be routed on top of ductwork serving that terminal unit for a maximum distance of eight feet.
- I. Tubing directly connected to steam valve actuators shall be copper tubing for a minimum of six inches.
- J. Where tubing is connected to ductwork at an exterior location for sensing purposes, the tubing shall be sloped to a heated interior location without sags or traps in the tubing to prevent condensation to be trapped in the tubing and prevent accurate sensing. Install drip leg at low point at interior location and note location on control record drawings.
- K. Number code all polyethylene tubing and install neatly with no concealed splices.
- L. Piping material used shall be as follows:
1. Polyethylene tubing in block, stud. or concrete walls must be in conduit and associated boxes to be of steel.
  2. Where air piping is within concrete slab or under grade use only polyethylene tubing in conduit
  3. For exposed outdoor locations, use hard copper or polyethylene tubing in conduit. Provide shielding for polyethylene tubing that is used for final device connection that will be exposed to direct sunlight.
  4. For static sensing lines connected to ductwork located in exposed outdoor locations, slope piping from connection into building to a location that will be above freezing so any condensation will run into the building and not freeze in piping. Piping tap shall not be on the bottom of the ductwork. Provide a drip leg of 3/8" tubing a minimum of one foot in length in an accessible location inside the building that will collect condensation from the sensing line.
  5. Polyethylene tubing may be used in exposed areas if run in a fully enclosed rigid metal raceway or metal conduit and ambient temperature is less than 150°F.

6. Use copper tubing, where subject to temperatures in excess of 150°F or where adjacent to heating pipes passing through a common sleeve.
7. When polyethylene tubing is used above accessible lay-in acoustical panel ceilings it must be fire resistance "FR" rated pass the UL 94 vertical flame test with a rating of V2, be rated as self-extinguishing under ASTM D 635, and may be run without conduit.

### **3.03 WIRE AND AIR PIPING CONDUIT AND TUBING INSTALLATION SCHEDULE**

- A. The following conduit schedule shall apply to both polyethylene tubing and wire in conduit where conduit is specified for air tubing or wiring. Conduit and tubing referenced below shall meet specifications in Division 26 and as defined below.
  1. Conduit other than that specified below for specific applications shall not be used.
  2. Underground Installations within Five Feet (1.5 m) of Foundation Wall: Rigid steel conduit.
  3. Underground Installations More than Five Feet (1.5 m) From Foundation Wall: Rigid steel conduit. Plastic-coated rigid steel conduit. Schedule 40 PVC conduit.
  4. Under Slab on Grade Installations: Schedule 40 PVC conduit.
  5. Exposed Outdoor Locations: Rigid steel conduit.
  6. Concealed in Concrete and Block Walls: Rigid steel conduit. Schedule 40 PVC conduit. Electrical Nonmetallic Tubing (ENT).
  7. Wet Interior Locations: Rigid steel conduit.
  8. Concealed Dry Interior Locations: Rigid steel conduit. Intermediate metal conduit. Electrical metallic tubing.
  9. Exposed Dry Interior Locations: Rigid steel conduit. Intermediate metal conduit. Electrical metallic tubing.

### **3.04 CONTROL DAMPERS**

- A. All control dampers furnished by the control manufacturer are to be installed by the Mechanical Contractor under the coordinating control and supervision of the Control Contractor in locations shown on plans or where required to provide specified sequence of control.
- B. Damper end switches, where required, shall be independently mounted to the damper drive shaft or auxiliary shaft attached to a damper drive blade. End switches shall be adjusted to prove the damper the position opposite the fail position of the damper actuator unless the control sequence requires a different position to be proven to accomplish the specified control sequence.
- C. Coordinate installation with the sheetmetal installer to obtain smooth duct transitions where damper size is different than duct size. Blank off plates will not be accepted.
- D. Each operator shall serve a maximum damper area of 36 square feet. Where larger dampers are used, provide multiple operators.

### **3.05 CONTROL VALVES**

- A. All temperature control valves furnished by the control manufacturer are to be installed by the Mechanical Contractor under the coordinating control and supervision of the Control Contractor in locations shown on plans or where required to provide specified sequence of control.
- B. Steam valve actuators shall be mounted at a 45 degree angle from upright vertical to prevent overheating of the actuator unless shielding is provided and the manufacturer indicates it is acceptable to mount in the upright vertical position. All other valves shall be mounted in the upright vertical position. If upright vertical mounting is not possible due to lack of space, obtain approval from the mechanical engineer of record on the project for alternate mounting that meet the manufacturers recommended installation.

### **3.06 ROOM THERMOSTATS AND TEMPERATURE SENSORS**

- A. Check and verify location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation. Room sensors/thermostats shall be mounted at existing locations. Any new locations should be installed at ADA height (42-48") and aligned with wall switches. For drywall installations, thermostat mounting shall use a back-box attached to a wall stud, drywall anchors are not acceptable.
- B. Any room thermostats or sensors mounted on an exterior wall shall be mounted on a thermally insulated sub-base. Subbase to provide a minimum of one half inch of insulation.
- C. Where thermostats or sensors are mounted on exterior walls or in any location where air transfer will affect the measured temperature or humidity seal the conduit and any other opening that will affect the measurement.

### **3.07 ZONE CO2 SENSORS**

- A. For rooms where a CO2 sensor and temperature sensor are both required, provide a combination device such that one wall sensor measures both temperature and CO2.

### **3.08 LOW LIMIT THERMOSTATS (FREEZESTATS)**

- A. Install low limit controls where indicated on the drawings or as specified. Unless otherwise indicated, install sensing element on the downstream side of heating coils.
- B. Mount units using flanges and element holders. Provide duct collars or bushings where sensing capillary passes through sheetmetal housings or ductwork; seal this penetration to eliminate air leakage. Mount the units in an accessible location as to allow for resetting after low limit trips while still meeting manufacturer's installation requirements for proper function.
- C. Distribute (serpentine) sensing element horizontally across the coil to cover every square foot of coil; on larger coils this may require more than one instrument. Install controls at accessible location with mounting brackets and element duct collars where required.
- D. Integral Face and Bypass Steam Heating Coil Freezestats:

1. For integral face and bypass coils the elements are to be run vertically on the face of the heating coil inside the damper enclosure, this will require drilling the frame to run element around the by-pass. Provide an auto-reset freezestat for each coil vertical heating tube. The head of the freezestat shall be mounted outside the unit, if possible, above the coils and any excess capillary shall be mounted out of the air stream above the coil. If the head of the freezestat cannot be mounted outside of the unit, it should be mounted downstream of the coil. Provide latching relays with LED indicator of relay status for each freezestat so that the relay will remain latched after the freezestat resets. Label each freezestat and corresponding relay to provide an easy method to determine which freezestat(s) have tripped. Provide a momentary reset switch and connection for remote contact reset from the DDC system for resetting the freezestat alarm. The relays shall be unlatched after a power fail. Mount latching relays in a hinged cover panel mounted at a maximum of five feet above the floor in an accessible location on the AHU. Reset switch shall be mounted on the cover and be labeled "Freezestat Reset".

### **3.09 AIRFLOW STATIONS**

- A. Install airflow stations in accordance with manufacturer's recommendations. Transmitter displays shall be mounted in accessible location for viewing and installation setup.

### **3.10 TEMPERATURE CONTROL PANELS**

- A. Mount control panels adjacent to associated equipment on vibration-free walls or freestanding angle iron supports. All control panel openings shall be plugged. Conduits and other penetrations on the top of the cabinets shall be sealed on the exterior of the cabinet with silicone caulk to resist water penetration. One cabinet may accommodate more than one system in same equipment room. Provide permanent printed labeling for instruments and controls inside cabinet and engraved plastic nameplates on cabinet face. Clear all debris and clean inside of cabinet at project closeout.
- B. Provide as-built control drawings of all systems served by each local panel in a location adjacent to or inside of panel cover.

### **3.11 CURRENT STATUS SWITCHES**

- A. Provide for each fan or pump specified, or shown on point list. Set threshold adjustment to indicate belt or coupling loss. Readjust threshold for proper operation after final balancing is completed. Use the variable frequency drive (VFD) integrated relay output for motor status, if provided on the VFD, in lieu of a discrete current switch. A separate current switch provided under this Section shall be wired in parallel with the VFD motor status relay when a bypass starter is provided on the VFD to prove motor status in the bypass mode.

### **END OF SECTION**

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**SECTION 23 09 93 - SEQUENCE OF OPERATIONS FOR HVAC CONTROLS**

**PART 1 GENERAL**

**1.01 SECTION INCLUDES**

- A. This section defines the manner and method by which controls function. Requirements for each type of control system operation are specified. Equipment, devices, and system components required for control systems are specified in other sections.
- B. Sequence of operation for:
  - 1. Hot Water System.
  - 2. Air Handling Units.
  - 3. Roof-Top Units.
  - 4. Exhaust Fan Systems.
  - 5. Air terminal units.
  - 6. Fan Coil Units.
  - 7. Zone Hot Water Coils.
  - 8. Unit Heaters.
  - 9. Emergency generators.

**1.02 RELATED REQUIREMENTS**

- A. Applicable provisions of Division 1 shall govern work under this section.
- B. Section 23 09 15 - DDC Points List
- C. Section 23 09 23 - Direct Digital Control (DDC) Systems
- D. Section 23 09 54 - Electric Temperature Control Systems

**1.03 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Shop Drawings: Submit shop drawings for each system automatically controlled, containing the following information:
  - 1. Schematic flow diagram of system showing fans, pumps, coils, dampers, valves and control devices. Indicate pneumatic piping; factory and field wiring.
  - 2. Label each control device with associated DDC point naming convention and applicable setting or adjustable range of control (e.g. HW-DP; 4-20mA/0-50psi).
  - 3. Indicate each control panel required, with internal and external piping and wiring clearly indicated. Provide detail of panel face, including controls, instruments and labeling.
  - 4. Include control narrative of the control sequence of each operation and interlocks with other operations.

- C. Maintenance Data: Include copy of "as-built" record shop drawings in each maintenance manual. Record drawings shall identify the location of concealed control devices by room number and location description.

## **PART 2 PRODUCTS - NOT USED**

## **PART 3 EXECUTION**

### **3.01 GENERAL**

- A. BACnet objects: All hardwired points listed in 23 09 15 and any setpoints, timers, or other control elements that are specified to be adjustable (adj.) in the following control sequences shall be mapped as BACnet objects and be available on the user interface to be adjusted. Consult with the user agency HVAC and/or DDC personnel prior to programming to determine if there are any items that they do not want to have mapped as BACnet objects. This is especially important for DDC controlled items that are duplicative, i.e. air terminal units.
- B. BACnet Addressing: BACnet instance ID's shall be coordinated with the agency's established BACnet instance ID addressing scheme. If there is not such a scheme in place, the contractor(s) providing BACnet DDC controllers shall work with the agency to establish such a scheme and document this in the asbuilt control drawings. BACnet/IP addressing shall be coordinated with the agency prior to installation. BACnet MS/TP addressing shall be addressed to provide for consecutive addressing to provide for the best speed of response.
- C. User Interface/Feature Software: Consult with the user agency HVAC and/or DDC personnel prior to programming to determine BACnet object naming conventions, user views, graphic layout, security matrix, alarming, trending, and scheduling preferences desired by the agency. Failure to consult and come to agreement prior to programming shall require the DDC contractor to make changes in the above listed items as desired by the user agency to the system at no cost.

- D. Setpoints: All setpoints indicated in the control specification are to be adjustable. The setpoints shall be readily available to be modified in the mechanical system software system summary (either textual or graphic based) and under the same software level as hardware points. Some less used setpoints may be provided on a lower software level, if requested by the user Agency for clarity. The setpoints indicated herein are only specified as a calculated starting point (or initial system operation). It is expected that setpoint adjustments and control loop tuning shall be required to provide optimum system operation based on requirements of the building. The control contractor shall work with the balancing contractor and the user Agency to provide the final system setpoint adjustments and control loop tuning after the system is in operation and building is in use. Document all final setpoints on the as-built control drawings. Any questions regarding the intended operation of the HVAC equipment and control systems shall be referred to the HVAC design engineer through the appropriate construction communication process. If the contractor fails to check with the user Agency for final setpoints, they shall adjust setpoints at no additional cost.
- E. Anti-Cycling: When HVAC equipment or a sequence is specified to be started and stopped by a temperature, humidity, pressure setpoint or any other controlled variable, there shall be an adjustable differential setpoint that shall be set to prevent short cycling of the systems and equipment due to minor changes in the controlled variable. Temperature differential setpoints shall be set at 2°F. Humidity setpoints shall be set at 5% of the controlled range unless otherwise specified. Setpoints shall indicate at when the process should be turned on. Heating and cooling differentials shall be set for above setpoint and will be used to turn the process off. For example, an economizer sequence called to switch at 68°F, would turn on at 68°F and off at 70°F since it is a cooling function. A heating lockout setpoint of 50°F would turn on heating control at 50°F and off at 52°F. Non-temperature differentials shall be set above setpoint if the setpoint is indicating a minimum value or below setpoint if the setpoint is indicating a maximum value. Provide minimum runtime timers for loads that are cycled to prevent over-cycling. Timers shall be set as specified or as needed to prevent damage or excessive wear to the equipment. Unless otherwise specified in the individual control sequences, fans and pumps shall have a minimum runtime on timers of 15 minutes (adj.) and off timers of 5 minutes (adj.). Safeties shall override runtime timers.
- F. Deadbands: Provide deadbands for all DDC control loops to prevent constant hunting of output signals to controlled devices. Deadbands shall be set to provide adequate control around setpoint as follows unless otherwise specified in the individual control sequences:
1. Temperature Control:  $\pm 0.5^{\circ}$  F
  2. Humidity Control:  $\pm 1\%$  RH
  3. Airflow Control:  $\pm 2\%$  of total flow
  4. AHU Static Pressure Control:  $\pm 0.01$  in. w.c.

G. Alarms

1. Provide all alarmed points with adjustable time delays to prevent nuisance tripping under normal operation and on equipment start-up. For all commanded outputs that have status feedback, provide an alarm that shall indicate the commanded output is not in its commanded state. Provide alarms on all points as indicated on 23 09 15 DDC point charts.
2. For devices that have form "C" contacts available for alarm monitoring, use closed contacts for the Normal condition and open contacts on Alarm condition. This shall provide a level of supervision by detecting a break in the wiring.

H. Lead/Lag Sequencing: For sequences that call for lead/lag of equipment connected to building automation systems, the lead device shall be able to be chosen through a selectable day of the week and time of day through the building automation system. Coordinate with the user Agency for scheduling switchover and frequency. Unless otherwise directed, switchover of equipment shall occur at 10AM Tuesday and shall rotate the lead device on a weekly cycle rotating through all devices sequentially.

I. Variable Frequency Drive (VFD) Motor Run Status: Use the VFD programmable relay dry contact output specified to be provided with the VFD to prove motor run status and detect belt loss or coupling break. If a bypass contactor is provided with the VFD, provide an adjustable current switch and wire it in parallel with the VFD output for proving motor status.

J. VFD Bypass and Safety Interlocks: VFD's equipped with bypass starters shall be interlocked so that the start/stop and safety circuits that are called out for VFD operation shall be functional when the VFD is indexed to the bypass starter mode. Unless otherwise specified in the sequence below, the switch from inverter to bypass starter modes shall be through a manual switch provided on the VFD/bypass starter package.

K. Damper Interlocks for Fans with Starters: For fan systems with magnetic starters and shutoff dampers specified with end switches, the damper interlock shall be hardwired in such a way that the damper shall open if the fan starter hand / off / auto switch is in the hand or in the auto position and being called to start. After the damper end switch has proven the damper open, a hardwire interlock from the end switch to the starter holding coil for the fan shall cause the fan to start. For fan systems that are ducted in parallel, see specific sequence for fan system on interlock requirements.

L. Damper Interlocks for Fans with VFD's:

1. For fan systems with VFD's and shutoff dampers specified with end switches, the damper end switches shall be hardwire interlocked to the safety circuit(s) of the VFD to prevent the fan from starting until the damper is proven open. This interlock shall prevent the fan from running in either the VFD or bypass (if provided) mode. The damper end switch shall also be monitored by the DDC system. For fan systems that are ducted in parallel, see specific sequence for fan system on additional interlock requirements.
- M. Thermostats and Sensors: All devices and equipment including terminal units, specified to be controlled in a control sequence by a thermostat or sensor, shall be provided with a thermostat or sensor, whether or not the device is indicated on the plans.

### **3.02 HOT WATER SEQUENCE OF OPERATIONS**

- A. General:
  1. Furnish and install a panel mounted DDC and controls devices (relays, current sensors, temperature sensors, pressure sensors, etc.) as depicted on HVAC controls schematics in plans in order to provide a fully-functional, controlled system.
  2. The hot water system is configured in a primary-secondary configuration with variable volume secondary pumps from an existing central boiler plant.
- B. Hot Water System Pumps:
  1. The building is served by two system hot water pumps that operate in a lead/lag/standby fashion. The building pumps are connected to an existing secondary heating hot water system with boiler and pumps located in the adjacent building. Control of the existing boilers and secondary pumps are to remain.
  2. The BAS shall modulate the variable frequency drive serving the respective pump(s) to maintain the system differential water pressure sensor at or above its respective setpoint of [10] psi (adj.). Work with TAB contractor to obtain the differential pressure setpoint for the sensor.
  3. Pumps shall operate in a lead/lag/standby fashion and shall run continuously. If the lead or lag hot water pump fails, the standby pump will automatically start and an alarm shall be provided at the BAS.
  4. When lead hot water pump speed has been greater than 80% for more than 10 minutes (adj.), the lag hot water pump shall be started and both pumps shall be commanded from a starting point of 40% speed. Both pumps shall be modulated in unison to maintain system differential pressure setpoint, as measure at the DPT with the lowest reading. When both pumps have modulated below 30% speed for more than 10 minutes (adj.), the lag pump shall be commanded off and the lead pump shall provide differential pressure control.

5. Provide a graphical button that allows manual selections of the lead, lag, and standby pumps for service. Lead, lag, and standby assignments shall rotate weekly to equalize runtime.

### **3.03 AIR HANDLING UNIT SYSTEMS**

- A. Variable Volume Air Handling Unit Control (AHU-1 ,2 and 3, RAHU-1,2)
  1. AHU control scope includes DDC control for new units and control retrofit of existing units. Refer to control diagrams and drawings for extent of new control devices.
  2. General:
    - a. The Air Handling Unit is controlled by Direct Digital Controls (DDC)
    - b. The Air Handling Unit serves VAV Boxes .
    - c. The AHU controls contains the following:
      - 1) Supply fan with VFD.
      - 2) Exhaust fan with VFD (external to unit).
      - 3) Fail-closed modulating outside air damper, fail-open modulating return air damper, and fail-closed relief air damper and actuator. Dampers shown in ductwork are furnished by this contractor, dampers included within the equipment or with roof exhaust fans are furnished by the manufacturer or are existing to remain; all actuators are furnished by this contractor.
      - 4) Hot water coil valve and modulating actuator for heating with freeze protection coil circulating pump.
      - 5) Chilled water coil valve and modulating actuator for cooling and dehumidification.
      - 6) Discharge air, return air and mixed air temperature sensors.
      - 7) Return air humidity sensor.
      - 8) Duct mounted static pressure sensor.
      - 9) High limit static pressure sensor.
      - 10) Smoke detector (furnished by E.C.).
      - 11) Filter air pressure drop differential sensor.
      - 12) Fan status feedback.
      - 13) Freeze protection thermostat.
  3. Ventilation (Outdoor Air) Air Flow Control:

- a. When the AHU is operating in the occupied mode, the outdoor air damper and return air damper shall be controlled to maintain the minimum ventilation airflow setpoint. The return air damper shall always modulate opposite of the outside air damper. When the economizer sequence is not enabled, the outside air damper and return air damper shall modulate to maintain the outside air flow ventilation rate setpoint. When the economizer sequence is enabled, the outside air and return air dampers shall modulate as described below under "Discharge Air Temperature Control" but shall be limited from controlling below the minimum outside air ventilation flow rate.
  - b. Ventilation Airflow Setpoint: The AHU outside air ventilation rate shall be the minimum flow rate as scheduled in the plans.
4. Discharge Air Temperature Control:
- a. Install a temperature sensor in the supply duct downstream of the supply fan, all coils, and humidifiers. The hot water heating coil, outdoor air damper and return air dampers, and chilled water coil shall be controlled in sequence to maintain the discharge air temperature setpoint. At no time shall the heating coil be operating when the mixed air dampers are economizing or the chilled water coil valve is open.
  - b. Discharge air temperature setpoint: Discharge air temperature setpoint shall be reset between 53°F and 65°F (adj.). The DDC system shall poll the supply VAV terminal operation and the RTU return air humidity and reset the discharge air temperature up in 0.5°F increments every 5 minutes and down in 1°F increments every 5 minutes. When none of the associated VAV boxes are at their maximum flow (except those that are constant volume – those shall be negated) and the return air humidity is below 53%RH, the discharge air temperature setpoint shall be reset up. When any of the associated VAV terminals are at 100% design airflow or the return air humidity rises above 58%RH, the system discharge air temperature setpoint shall be reset down.
  - c. Whenever the discharge air temperature is above the setpoint, the following shall occur in sequence: The heating coil control valve shall modulate closed as sequenced below. When heating is completely off and the economizer sequence is enabled, the economizer outside air damper and return air damper shall be modulated to maintain the discharge air temperature setpoint. When the outside air economizer damper is completely open and the return air damper is completely closed, or the economizer sequence is not enabled, the chilled water valve shall modulate open to maintain the discharge air temperature setpoint. When the discharge air setpoint is below setpoint the reverse shall occur and the heating coil control valve shall modulate to maintain discharge air temperature setpoint. Cooling coil control shall be locked out below 50° F (adj.) outside air temperature.

5. Pumped Hot Water Heating Coil Control:
  - a. Modulate the hot water control valve as sequenced under discharge air control. Start hot water pump whenever mixed air temperature is below 45° F (adj.). Stop hot water pump whenever mixed air temperature is above 45° F (adj.).
6. Economizer Control:
  - a. Economizer shall be enabled whenever outdoor air temperature is less than 70°F (adj.).
7. Relief Air Damper and Exhaust Fan Control:
  - a. Install a building static pressure sensor to control the relief air damper and exhaust fan (external to unit). Locate the static pressure sensor away from any air intake or exhaust airstreams.
  - b. When the building static pressure rises above +0.05"WC (adj.), the relief air damper shall be commanded open. Upon a further increase in building static pressure, the exhaust fan VFD shall be modulated to maintain the building pressure at a setpoint of +0.02"WC (adj.). The relief damper shall be open anytime the exhaust fan is on.
8. Dehumidification Control:
  - a. The discharge air temperature shall be reset as described above under "Discharge Air Temperature Control" to dehumidify the supply air by lowering the discharge air temperature, based on return air humidity.
9. Filters:
  - a. Install a differential static pressure sensor across each filter bank. Ensure that the static probes do not impede filter removal.
  - b. For MERV 8 filter bank, provide an alarm at the BAS when the differential static pressure exceeds 1.00" w.c. (adj.).
  - c. For MERV 13 filter bank, annunciate an alarm at the BAS when the differential static pressure exceeds 1.5" w.c. (adj.).
10. Unoccupied Control:
  - a. Occupied/unoccupied schedule shall be set at the BAS. Preliminary schedule shall be determined in coordination with the facility owner. When indexed to unoccupied, the unit shall shutdown. Index VAV boxes associated with this AHU to maintain setback and start-up temperature setpoints during unoccupied mode.

- 1) Night Setback Heating: If the space temperature in any of the VAV zones served drops below its unoccupied heating setpoint, all VAV Boxes shall be commanded to operate between their occupied minimum CFM setpoints and heating and cooling maximums. The supply fan shall start, the outdoor air and exhaust air dampers shall remain closed, the return air damper shall be open, and the heating coil valve shall modulate to provide heat. The relief fan shall be off. When the space temperature rises above the unoccupied heating setpoint, the AHU shall stop and all VAV Boxes shall go to their unoccupied minimum CFM setpoints. Provide a minimum runtime of 15 minutes (adj.).
  - 2) Night Setback Cooling: If the space temperature in any of the VAV zones rises above its unoccupied cooling setpoint, all VAV Boxes shall be commanded to operate between their occupied minimum CFM setpoints and heating and cooling maximums. The supply fan shall start. The outdoor air and exhaust air dampers shall remain closed, the return air damper shall be open, the relief fan shall be off, and the cooling coil valve shall be modulated to maintain the discharge air setpoint. Provide a minimum runtime of 15 minutes (adj.).
- b. Heating Optimum Start-Up:
- 1) This cycle shall override the unoccupied cycle. If the system was operating as a result of the unoccupied cycle, the system shall continue to operate. The BAS shall measure the outside air dry bulb temperature to determine the minimum run time to warm the zone to its setpoint. When the computed start time is reached, the DDC system shall start the Air Handling Unit and operate with the outside air and relief air dampers closed and the return air damper open. The Air Handling Unit discharge air temperature shall be controlled as specified under Discharge Air Temperature Control. When the occupied time is reached, the unit shall be switched to occupied control and ventilation air shall be provided.
  - 2) Anytime the unit is on for heating optimum start-up, all VAV boxes shall be overridden open to their occupied minimum flow values for minimum flow (instead of their scheduled unoccupied minimum airflow value) and modulated between their occupied minimum and heating and cooling maximum airflows.
- c. Cooling Optimum Start-Up:
- 1) This cycle shall override the unoccupied cycle. If the system was operating as a result of the unoccupied cycle, the system shall continue to operate. The BAS shall measure the outside air dry bulb temperature to determine the minimum run time to cool the zone to its setpoint. When the computed start time is reached, the DDC system shall start the Air Handling Unit. When the occupied time is reached, the unit shall be switched to occupied control and ventilation air shall be provided.
  - 2) Anytime the unit is on for cooling optimum start-up, all VAV boxes shall be overridden open to their occupied minimum flow values for minimum flow (instead of their scheduled unoccupied minimum airflow value) and modulated between their occupied minimum and heating and cooling maximum airflows.

11. Safeties:

- a. General: All safeties shall be hard wired to the supply fan starter or VFD safety circuits except where noted to be a software shutdown only. Starters shall not function in the "Hand" or "Auto" and VFD's shall be disabled if they are indexed to the "Auto" or "Hand" position in either the VFD or bypass modes. All alarms shall be annunciated at the BAS in addition to unit shutdown.
  - b. Fire Alarm Shutdown: Upon a fire alarm system alarm, the fire alarm control module provided by the electrical contractor at the temperature control panel shall change its state of contacts. This shall cause the unit to be shut down (see Unit Shutdown for additional information) and all fire/smoke and smoke dampers within this system shall close immediately through a hardwire interlock.
  - c. Low Limit Temperature (software shutdown only): If the unit discharge air temperature drops below 38°F (adj), the AHU shall be commanded off by the BAS and an alarm shall be sent to the BAS. Provide a graphical reset button that puts the AHU back into service after this event.
  - d. Freezestat: Install an electric freezestat to shut down the unit (see Unit Shutdown for additional information) if the temperature downstream of the heating coil drops below 35° F (adj.). The electric freezestat shall act independently of the DDC system via hardwire interlock and shall override the DDC system control signal to open the heating coil control valve(s). A freezestat trip shall notify the DDC system that shall send an alarm to the BAS.
  - e. Supply Fan High Pressure Limit: Install a static pressure probe located in the air handling unit main discharge duct at least six feet or as far as physically possible downstream of the fan and upstream of any dampers and pipe to a differential pressure switch located in the temperature control panel. Wire in series with the safety circuit of the supply and return fan. Differential pressure switch shall be a manual reset type and the DDC system shall monitor the status of the differential pressure switch. Initial setpoint shall be +3.5" w.c. (adj.).
  - f. Smoke Detector Shutdown: Upon activation of the smoke detector in the RTU return duct, this shall cause the supply and return fan to be off via a hardwired interlock and the unit to be shut down (see Unit Shutdown for additional information). An auxiliary contact shall be provided to notify the DDC system of a smoke detector shutdown.
12. Unit Shutdown:
- a. Whenever the Air Handling Unit is off, the following shall occur:
    - 1) The supply fan shall be off.
    - 2) The relief fan shall be off.
    - 3) The outside air damper and relief air damper shall close and the return damper shall open.

- 4) The chilled water control valve shall close.
- 5) The heating coil control valve shall remain under control from the mixed air sensor to maintain 55°F (adj). Freezestat shall override heating control valve open.

### **3.04 ROOF TOP UNITS**

#### **A. Variable Volume Roof-Top Unit Control (RTU-1)**

##### **1. General:**

- a. The Roof-Top Unit is variable air volume but will operate as constant airflow, packaged unit for roof installation.
- b. The Roof-Top Unit is controlled by Direct Digital Controls (DDC) provided by this contractor.
- c. The Roof-Top Unit serves zone heating coils.
- d. The Roof-Top Unit controls contains the following:
  - 1) Supply with VFD
  - 2) Exhaust fan with VFD
  - 3) Fail-closed modulating outside air damper, fail-open modulating return air damper. Dampers and actuators provided with unit by manufacturer.
  - 4) DX coil for cooling and dehumidification.
  - 5) Return air humidity sensor.
  - 6) Duct mounted static pressure sensor.
  - 7) High limit static pressure sensor.
  - 8) Filter air pressure drop differential sensor.
  - 9) Fan status feedback.
  - 10) Terminal strip for DDC control of unit by BAS.
  - 11) Smoke detector (furnished by E.C.).

##### **2. Supply Fan Control:**

- a. Start/Stop: Provide a user-defined building occupancy schedule. Preliminary schedule shall be determined in coordination with the facility owner. During occupied mode, the supply fan shall operate continuously. The supply fan shall be off in the unoccupied mode except as described below for night setback cycling and optimal start.
- b. Supply Fan Speed Control: The supply fan operates at constant volume with variable speed drive for balancing purposes and future VAV conversion.

- c. Static Pressure Reset Control: Static pressure setpoint shall be reset using Trim & Respond logic within the range 0.15 in. W.C. to 1.25 in. w.c. (adj.) When the fan is off, the setpoint shall be reset to 0.8 in. w.c. (adj.) and this setpoint shall be used on system start up while the fan is proven on, every two minutes, trim the setpoint by 0.04 in. w.c. if there are two or fewer zone pressure requests. If there are more than two zone pressure requests, respond by increasing the setpoint by 0.06 in. w.c.
- 3. Exhaust Fan Control:
  - a. Start/Stop and Exhaust Fan Speed Control: The exhaust fan shall be commanded through the DDC system and shall modulate the exhaust fan VFD to maintain the building static pressure setpoint.
  - b. When the building static pressure rises above +0.05"WC (adj.), the relief air damper shall be commanded open. Upon a further increase in building static pressure, the exhaust fan VFD shall be modulated to maintain the building pressure at a setpoint of +0.02"WC (adj.). The relief damper shall be open anytime the exhaust fan is on.
- 4. Mixed Air Dampers and Ventilation Air Control:
  - a. When outdoor air temperature is between the discharge air temperature setpoint and economizer setpoint of 70°F, the outdoor air damper shall be 100% open for economizer and the return air damper closed.
  - b. When the outdoor air temperature is above 70°F, the mixed air dampers shall modulate to maintain the required ventilation levels as scheduled in the plans.
  - c. When the outdoor air temperature is below the discharge air temperature setpoint, the mixed air dampers shall modulate to maintain discharge air temperature setpoint, subject to the required ventilation levels.
- 5. Discharge Air Temperature Control:
  - a. Install a temperature sensor in the supply duct downstream of all coils.
  - b. Discharge Air Temperature Control: The mixed air dampers, heating coil, and the cooling coil shall be controlled in sequence to maintain the discharge air setpoint temperature. Whenever the discharge air temperature is above the setpoint, the following shall occur in sequence: When the economizer sequence is enabled, the economizer outside air damper and return air damper shall be modulated together to maintain discharge air temperature setpoint, subject to ventilation levels. When the outside air economizer damper is completely open, or the economizer sequence is not enabled, the cooling coil valve shall modulate to maintain the discharge air temperature setpoint. When the discharge air setpoint is below setpoint the reverse shall occur. The heating coil valve will be off anytime the unit is economizing or the cooling coil is operating in the cooling mode.
- 6. Economizer Control:

- a. When the economizer sequence is enabled by the switchover sequence below, the outside air damper and return air damper will modulate to provide outside air to be used for free cooling. The dampers will modulate in sequence with the cooling coil as described in the discharge air temperature control sequence above. The heating coil shall be energized off when economizer dampers are open for cooling.
  - b. Fixed Dry Bulb Economizer Switchover: The economizer sequence shall be enabled whenever the outside air temperature is less than 70° F (adj.).
7. Filters:
  - a. Monitor the RTU's dirty filter switch and provide an alarm to the operator interface when the switch is in alarm.
8. Safeties:
  - a. General: All safeties shall be hard wired to the supply and exhaust fan VFD safety circuits. Starters shall not function in the "Hand" or "Auto" and VFD's shall be disabled if they are indexed to the "Auto" or "Hand" position in either the VFD or bypass modes.
  - b. Supply Fan High Pressure Limit: Install a static pressure probe located in the Roof-Top Unit main discharge duct at least six feet or as far as physically possible downstream of the fan and upstream of any dampers and pipe to a differential pressure switch located in the temperature control panel. Wire in series with the safety circuit of the supply fan. Differential pressure switch shall be a manual reset type and the DDC system shall monitor the status of the differential pressure switch. Initial setpoint shall be +3.5" W.C. (adj.)
  - c. Return Air Low Pressure Limit: Install a static pressure probe located in the return ductwork and pipe to a differential pressure switch located in the temperature control panel. Wire in series with the safety circuit of the supply and exhaust fans. Differential pressure switch shall be a manual reset type and the DDC system shall monitor the status of the differential pressure switch. Initial setpoint shall be - 3.5" w.c. (adj.).
  - d. Smoke Detector Shutdown: Upon activation of the smoke detector in the RTU return duct, this shall cause the supply and return fan to be off via a hardwired interlock and the unit to be shut down (see Unit Shutdown for additional information). An auxiliary contact shall be provided to notify the DDC system of a smoke detector shutdown.
9. Unit Shutdown:
  - a. Whenever the Roof-Top Unit is off, the following shall occur:
    - 1) The supply and exhaust fans shall be off.
    - 2) The outside air dampers and exhaust air dampers shall close and the return dampers shall open.

- 3) The cooling coil compressors shall be off.

### **3.05 EXHAUST FANS**

#### **A. General Exhaust Fan:**

1. System consists of multiple existing or new constant volume exhaust fans with motorized isolation dampers, furnished by the manufacturer or existing to remain. VFD/ECM for balancing purposes only.
2. Exhaust fan shall be commanded on by the BAS to run based on the occupancy schedule. Interlock damper to open with fan operation.

#### **B. Light Well Exhaust Fan Cooling:**

1. System consists of two existing constant volume exhaust fan with isolation dampers wired to each fan and two existing transfer air ducts with new dampers and actuators furnished by this contractor. Provide a new space DDC sensor within the light well zone.
2. When the DDC space temperature sensor rises above 80°F (adj), the BAS shall command on the exhaust fan and open the transfer duct damper. Interlock exhaust fan with exhaust isolation damper. When the room temperature drops below 75°F (adj), the fan shall be off. Any time the exhaust fan is called to run, provide a 15-minute minimum runtime on the fan before the fan is allowed to turn off.

### **3.06 AIR TERMINAL UNITS**

#### **A. VAV Terminal Unit with Reheat:**

1. Provide a DDC space temperature sensor to control, in sequence, a modulating electronic control valve for the hot water reheat coil and actuator for terminal air flow. On a rise in temperature above the room temperature setpoint, the reheat coil will modulate closed. On a further rise in temperature, the VAV box will be modulated open beyond the minimum CFM towards the maximum cooling CFM in order to maintain the desired room temperature setpoint. When space temperature is below setpoint, the air terminal damper shall modulate toward the cooling minimum flow position. After the air terminal damper is at its minimum flow, the hot water valve shall modulate open to maintain space temperature, while limiting the discharge air temperature from exceeding 90°F. If the discharge air temperature is at 90°F and there is still a call for heating, the air terminal damper shall modulate towards the heating maximum flow position and the control valve shall be released to maintain room temperature.
2. The heating coil valve shall be commanded closed whenever the associated AHU/RTU is off. When the space temperature is between the heating and cooling setpoints, the heating valve shall be closed and the supply airflow at minimum flow.

3. Radiation Control: For zones with associated radiation, when space temperature is below setpoint, the air terminal damper shall modulate toward the cooling minimum flow position. On a further call for heat, modulate radiant hot water valve open as the first stage of heat. If valve is 100% open and there is a further call for heating, the reheat coil shall be modulated open as the second stage of heat to maintain space temperature. On a further call for heating after the hot water reheat valve is 100% open, the air terminal damper shall modulate up to the maximum heating flow (where scheduled). The reverse shall occur when space temperature is above setpoint. Lock hot water radiation valve closed whenever outside air is above 50° F (adj.).
4. Unoccupied/Standby Heating Control with Radiation: If there is a call for zone heating, the associated radiation terminal shall be modulated to maintain the unoccupied/standby zone temperature. If there is a further call for heating, the VAV terminal shall modulate between the minimum and heating maximum occupied airflow rates and the heating valve controlled to maintain zone setpoint
5. Unoccupied/Standby Heating Control without Radiation: When there is a call for zone heating, the VAV terminal shall modulate between the minimum and heating maximum occupied airflow rates and the heating valve controlled to maintain zone setpoint.
6. Demand Control Ventilation: For zones that show a CO2 sensor on the plans, the minimum box CFM shall be overridden based on the CO2 sensor reading in the occupied mode. When the space is scheduled to the occupied mode, the minimum box CFM shall be overridden and reset between the scheduled minimum airflow up to the heating maximum airflow as CO2 in the space goes between 500ppm and 1200ppm.
7. Hot water coil freeze protection sequence - VAV 2-15 located in the attic: When its associated air handling unit is off, monitor the discharge air temperature sensor and modulate the hot water heating control valve to maintain 60F inside the duct.

### **3.07 ZONE HOT WATER HEATING COILS:**

- A. Provide a DDC space temperature sensor to control a modulating electronic control hot water valve to maintain space temperature. When space temperature is below setpoint, modulate the hot water valve open. The reverse shall occur when space temperature is above setpoint.
- B. Provide separate adjustable heating setpoints for both the occupied and unoccupied modes.

### **3.08 FAN COIL HEATING/COOLING:**

- A. Provide a DDC space temperature sensor to control modulating control valves for hot water and for chilled water to maintain space temperature. Provide separate heating and cooling setpoints. When the space temperature is below setpoint, the DDC controller shall modulate the chilled water valve closed. When the chilled water valve is fully closed the hot water valve shall modulate open to maintain setpoint. When the space temperature is above setpoint, the DDC controller shall modulate the hot water valve closed. When the hot water valve is fully closed, the chilled water valve shall modulate open to maintain setpoint.
- B. Provide a DDC space temperature sensor and discharge air temperature sensor to control, in sequence, an ECM fan, and modulating control valves for hot water and for chilled water to maintain space temperature. Reset the discharge air temperature setpoint based on the zone temperature between 55° F (adj.) and 85°F to maintain the zone heating and cooling setpoints. When the space temperature is below setpoint, the DDC controller shall start the fan at minimum speed and modulate the chilled water valve closed. When the chilled water valve is fully closed the hot water valve shall modulate open to maintain target discharge air setpoint. If the heating valve is opened 100% and there is still a call for heating, the fan speed shall be modulated upwards to maintain setpoint. When the space temperature is above setpoint, the following shall occur in sequence: The fan shall start at minimum speed and the chilled water valve shall modulate open to maintain the space temperature setpoint. Modulate fan speed upwards as the final stage of cooling. When space is satisfied fan shall be off. Provide a minimum runtime of 15 minutes (adj.) to prevent short-cycling. The heating and cooling coil valves shall be commanded closed whenever the fan coil fan is off.
- C. Provide DDC start/stop for fan control. Cycle fan on when calling for heating or cooling. When space is satisfied fan shall be off.
- D. Provide a discharge temperature for monitoring purposes. The heating and cooling coil valves shall be commanded closed whenever the fan coil fan is off.

### **3.09 HOT WATER UNIT HEATERS:**

- A. Provide DDC space temperature sensor to control the hot water control valve to maintain space temperature. As temperature rises above setpoint, the control valve shall be closed. On a call for heating, the hot water valve shall be open. Provide a strap-on aquastat on the hot water return line set at 100°F to control the unit fan whenever the hot water temperature is above setpoint.

### **3.10 EMERGENCY GENERATORS**

- A. Provide BAS integration and monitoring of the generator. Points to be monitored and alarmed, at a minimum, include: Generator Status, Run, Trouble, and Fuel Level.

**3.11 FINAL ADJUSTMENT OF EQUIPMENT**

- A. After completion of installation of the DDC equipment, calibrate and adjust setpoints of the equipment provided as work of this section.
- B. All controllers, relays, sensors/transmitters, wiring leads, and other devices shall be neatly identified as to function and adjustment (with final setpoint marked and numerically identified).
- C. Final adjustment shall be performed by specially trained personnel in direct employ of manufacturer of the control system.

**END OF SECTION 23 09 93**

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## **SECTION 23 21 13 - HYDRONIC PIPING**

### **PART 1 GENERAL**

#### **1.01 SECTION INCLUDES**

- A. Hydronic system requirements.
- B. Heating water piping.
- C. Make-up water.
- D. Drain piping.
- E. Chilled water piping.
- F. Unions, flanges, and dielectric connections.

#### **1.02 RELATED REQUIREMENTS**

- A. Section 23 05 16 - Expansion Fittings and Loops for HVAC Piping.
- B. Section 23 07 19 - HVAC Piping Insulation.
- C. Section 23 25 00 - HVAC Water Treatment: Pipe cleaning.

#### **1.03 REFERENCE STANDARDS**

- A. ASME B16.3 - Malleable Iron Threaded Fittings: Classes 150 and 300.
- B. ASME B16.18 - Cast Copper Alloy Solder Joint Pressure Fittings.
- C. ASME B16.22 - Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings.
- D. ASME B31.9 - Building Services Piping.
- E. ASME BPVC-IX - Boiler and Pressure Vessel Code, Section IX - Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators.
- F. ASTM A53/A53M - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
- G. ASTM A234/A234M - Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service.
- H. ASTM B32 - Standard Specification for Solder Metal.
- I. ASTM B88 - Standard Specification for Seamless Copper Water Tube.
- J. ASTM B88M - Standard Specification for Seamless Copper Water Tube (Metric).
- K. ASTM F708 - Standard Practice for Design and Installation of Rigid Pipe Hangers.
- L. AWS A5.8M/A5.8 - Specification for Filler Metals for Brazing and Braze Welding.
- M. AWS D1.1/D1.1M - Structural Welding Code - Steel.
- N. MSS SP-58 - Pipe Hangers and Supports - Materials, Design, Manufacture, Selection, Application, and Installation.

#### **1.04 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.

- B. Product Data:
  - 1. Include data on pipe materials, pipe fittings, and accessories.
  - 2. Indicate valve data and ratings.
- C. Manufacturer's Installation Instructions: Indicate hanging and support methods, joining procedures.
- D. Project Record Documents: Record actual locations of valves.
- E. Maintenance Data: Include installation instructions, spare parts lists, exploded assembly views.

#### **1.05 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacturing products of the type specified in this section, with minimum three years of documented experience.
- B. Welder Qualifications:
  - 1. Welding procedures, welders, and welding operators for all building service piping to be in accordance with certified welding procedures of the National Certified Pipe Welding Bureau.
  - 2. The Architect, Engineer or Owner reserves the right to test the work of any welder employed on the project, at the Contractor's expense. If the work of the welder is found to be unsatisfactory, the welder shall be prevented from doing further welding on the project.

#### **1.06 DELIVERY, STORAGE, AND HANDLING**

- A. Provide temporary end caps and closures on piping and fittings. Maintain in place until installation.
- B. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.

### **PART 2 PRODUCTS**

#### **2.01 HYDRONIC SYSTEM REQUIREMENTS**

- A. Comply with ASME B31.9 and applicable federal, state, and local regulations.
- B. Piping: Provide piping, fittings, hangers, and supports as required, as indicated, and as follows:
  - 1. Where more than one piping system material is specified, provide joining fittings that are compatible with piping materials and ensure that the integrity of the system is not jeopardized.
  - 2. Use non-conducting dielectric connections whenever jointing dissimilar metals.
- C. Pipe-to-Valve and Pipe-to-Equipment Connections: Use flanges to allow disconnection of components for servicing; do not use direct welded, soldered, or threaded connections.
- D. Valves: Provide valves where indicated:
  - 1. Provide drain valves where indicated, and if not indicated, provide at least at main shut-off, low points of piping, bases of vertical risers, and at equipment. Use 3/4 inch ball valves with cap; pipe to nearest floor drain.

2. Isolate equipment using butterfly valves with lug end flanges.
  3. For throttling, bypass, or manual flow control services, use ball or butterfly valves.
  4. For throttling and isolation service in chilled water systems, use only butterfly valves.
  5. For shut-off and to isolate parts of systems or vertical risers, use ball or butterfly valves.
- E. Welding Materials and Procedures: Comply with ASME BPVC-IX.
- F. "Weldolets" may be used for branch takeoffs up to one-half (1/2) the diameter of the main.

## **2.02 HEATING WATER PIPING**

- A. Steel Pipe: ASTM A53/A53M, Schedule 40, black, using one of the following joint types:
1. Welded Joints: ASTM A234/A234M, wrought steel welding type fittings; AWS D1.1/D1.1M welded.
  2. Threaded Joints: ASME B16.3, malleable iron fittings.
- B. Copper Tube: ASTM B88, Type K, drawn, using one of the following joint types:
1. Solder Joints: ASME B16.18 cast brass/bronze or ASME B16.22 solder wrought copper fittings.
    - a. Solder: ASTM B32 lead-free solder, HB alloy (95-5 tin-antimony) or tin and silver.
    - b. Braze: AWS A5.8M/A5.8 BCuP copper/silver alloy.
  2. Mechanical Press Sealed Fittings: Double pressed type complying with ASME B16.22, utilizing EPDM, nontoxic synthetic rubber sealing elements.
    - a. Manufacturers:
      - 1) Apollo Valves: [www.apollovalves.com/#sle](http://www.apollovalves.com/#sle).
      - 2) Grinnell Products: [www.grinnell.com/#sle](http://www.grinnell.com/#sle).

## **2.03 CHILLED WATER PIPING**

- A. Steel Pipe: ASTM A53/A53M, Schedule 40, black; using one of the following joint types:
1. Welded Joints: ASTM A234/A234M, wrought steel welding type fittings; AWS D1.1/D1.1M welded.
  2. Threaded Joints: ASME B16.3, malleable iron fittings.
- B. Copper Tube: ASTM B88, Type K, hard drawn; using one of the following joint types:
1. Solder Joints: ASME B16.18 cast brass/bronze or ASME B16.22, solder wrought copper fittings.
    - a. Solder: ASTM B32 lead-free solder, HB alloy (95-5 tin-antimony) or tin and silver.
    - b. Braze: AWS A5.8M/A5.8 BCuP copper/silver alloy.
  2. Tee Connections: Mechanically extracted collars with notched and dimpled branch tube.
  3. Mechanical Press Sealed Fittings: Double pressed type complying with ASME B16.22, utilizing EPDM, nontoxic synthetic rubber sealing elements.
    - a. Manufacturers:
      - 1) Apollo Valves

2) Grinnell Products

**2.04 EQUIPMENT DRAINS AND OVERFLOWS**

- A. Steel Pipe: ASTM A53/A53M, Schedule 40 galvanized; using one of the following joint types:
  - 1. Threaded Joints: Galvanized cast iron, or ASME B16.3 malleable iron fittings.

**2.05 UNIONS, FLANGES, DIELECTRIC CONNECTIONS**

- A. Unions for Pipe of 2 Inches and Less:
  - 1. Ferrous Piping: 150 psi brass or malleable iron, threaded.
  - 2. Copper Pipe: Bronze, soldered joints.
- B. Flanges for Pipe 2 1/2 Inches and Greater:
  - 1. Ferrous Piping: 150 psig forged steel, slip-on.
  - 2. Copper Piping: Bronze.
  - 3. Gaskets: 1/16 inch thick, preformed neoprene.
- C. Dielectric Connections: Utilize brass or bronze threaded ball valves at transitions between steel mains and copper branch connections to limit the effects of galvanic action.

**PART 3 EXECUTION**

**3.01 PREPARATION**

- A. Ream pipe and tube ends. Remove burrs. Bevel plain end ferrous pipe. Tubing end shall be clean and dry.
- B. Remove scale and dirt on inside and outside before assembly.
- C. Prepare piping connections to equipment using jointing system specified.
- D. Keep open ends of pipe free from scale and dirt. Protect open ends with temporary plugs or caps.
- E. After completion, fill, clean, and treat systems. See Section 23 25 00 for additional requirements.

**3.02 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Route piping in orderly manner, parallel to building structure, and maintain gradient.
- C. Install piping to conserve building space, to avoid interfere with use of space, and at heights which do not obstruct other trades or any portion of a window, doorway, stairway, or passageway.
- D. Group piping whenever practical at common elevations.
- E. Slope piping and arrange to drain at low points.
- F. Install piping to allow for expansion and contraction without stressing pipe, joints, or connected equipment.

- G. Provide clearance in hangers and from structure and other equipment for installation of insulation and access to valves and fittings. See Section 23 07 19.
- H. Use eccentric reducers to maintain top of pipe level.
- I. Connect branch piping to mains at 90 degree angle upward.
- J. Do not route piping through transformer vaults, elevator equipment rooms, or above transformers, panel boards, or switchboards, including the required service space for this equipment, unless the piping is serving this equipment. Where the above condition is unavoidable, provide drain pan and side shields to protect equipment from dripping or spraying.
- K. Use a thread lubricant or Teflon tape when making threaded pipe joints; no hard setting pipe thread cement or caulking will be allowed.

**END OF SECTION**

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## **SECTION 23 21 14 - HYDRONIC SPECIALTIES**

### **PART 1 GENERAL**

#### **1.01 SECTION INCLUDES**

- A. Expansion tanks.
- B. Air vents.
- C. Air and dirt separators.
- D. Strainers.
- E. Suction diffusers.
- F. Pressure-temperature test plugs.
- G. Balancing valves.
- H. Flow meters.
- I. Relief valves.

#### **1.02 REFERENCE STANDARDS**

- A. ASME BPVC-VIII-1 - Boiler and Pressure Vessel Code, Section VIII, Division 1: Rules for Construction of Pressure Vessels.

#### **1.03 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide product data for manufactured products and assemblies required for this project. Include component sizes, rough-in requirements, service sizes, and finishes. Include product description and model.
- C. Certificates: Inspection certificates for pressure vessels from authority having jurisdiction.
- D. Manufacturer's Installation Instructions: Indicate hanging and support methods, joining procedures.
- E. Project Record Documents: Record actual locations of flow controls.
- F. Maintenance Data: Include installation instructions, assembly views, lubrication instructions, and replacement parts list.
- G. Maintenance Materials: Furnish the following for Owner's use in maintenance of project.
  - 1. See Section 01 60 00 - Product Requirements for additional provisions.

#### **1.04 DELIVERY, STORAGE, AND HANDLING**

- A. Accept valves on site in shipping containers with labeling in place. Inspect for damage.
- B. Provide temporary end caps and closures on piping and fittings. Maintain in place until installation.
- C. Protect piping systems from entry of foreign materials by temporary covers, completing sections of the work, and isolating parts of completed system.

## **PART 2 PRODUCTS**

### **2.01 EXPANSION TANKS**

- A. Manufacturers:
  - 1. Amtrol
  - 2. ITT Bell & Gossett
  - 3. Taco
  - 4. Substitutions: See Section 01 60 00 - Product Requirements.
- B. ASME stamped for 125 PSIG working pressure.
- C. Vertical pressurized steel tank.
- D. Each complete with replaceable heavy duty butyl rubber bladder, 1-1/2" system connection, 3/4" drain connection, charging valve connection and lifting ring and floor mounting skirt for vertical mounting.
- E. Construction: Welded steel, tested and stamped in accordance with ASME BPVC-VIII-1; supplied with National Board Form U-1, adjustable flexible EPDM diaphragm or bladder seal factory precharged to 12 psi, and steel support stand.
- F. Automatic Cold Water Fill Assembly: Pressure reducing valve, reduced pressure double check backflow preventer, test cocks, strainer, vacuum breaker, and valved by-pass.

### **2.02 AIR VENTS**

- A. Manufacturers:
  - 1. Armstrong
  - 2. ITT Bell & Gossett
  - 3. Taco
  - 4. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Manual Air Vent: Short vertical sections of pipe to form air chamber, with 1/8 inch brass needle valve at top of chamber.
- C. Float Air Vent:
  - 1. High capacity air vent rated for 150 PSIG at a maximum temperature of 250 deg.
    - F. Constructed of cast iron body and fitted with components of stainless steel, brass and EPDM.

### **2.03 AIR SEPARATORS**

- A. Air and Dirt Separators:
  - 1. Manufacturers:
    - a. Armstrong
    - b. ITT Bell & Gossett
    - c. Spirotherm
    - d. Substitutions: See Section 01 60 00 - Product Requirements.

2. Furnish in-line air and dirt separator of size indicated with steel body, stainless steel coalescing medium, bottom collection chamber, removable top air vent, side-tap hose connection, minimum 1" bottom blow-down tapping with ball valve, ASME constructed and stamped for 150 PSIG working pressure with flanged connections.
3. Air Vent: Integral float actuated air vent at top fitting of tank rated at 150 psi, threaded to top of separator.
4. End Connections: Class 150 flanged for 2-1/2 inch and larger otherwise threaded.
5. Blowdown Connection: Threaded.
6. Size: Match system flow capacity.
7. Maximum Fluid Service Pressure: 150 psi.
8. Maximum Fluid Service Temperature: 250 degrees F.

## **2.04 STRAINERS**

- A. Manufacturers:
  1. Armstrong
  2. Grinnell
  3. Nexus Valve
  4. The Metraflex Company: [www.metralflex.com/#sle](http://www.metralflex.com/#sle).
  5. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Size 2 inch and Under:
  1. Provide threaded or sweat brass or iron body for up to 175 psi working pressure, Y-pattern strainer with 1/32 inch stainless steel perforated screen.
  2. Body Material by Fluid Service:
    - a. Cast Iron or Brass:
      - 1) Liquids: Up to 400 psi at 150 degrees F.
- C. Size 2-1/2 inch to 4 inch:
  1. Provide iron body for 175 psi working pressure, Y pattern with 1/16 inch stainless steel perforated screen.
  2. Body Material by Fluid Service:
    - a. Cast Iron:
      - 1) Liquids: Up to 200 psi at 150 degrees F.
- D. Accessories: Provide air vent, hanging tag, outlet ball valve, and PT test plug extension.

## **2.05 SUCTION DIFFUSERS**

- A. Manufacturers:
  1. Bell & Gossett
  2. Grinnell
  3. Victaulic

4. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Furnish cast iron angle type body with steel inlet vanes, steel combination diffuser strainer and orifice plate and a number 16 mesh bronze start-up strainer, which is to be removed after initial 30-days of operation, an adjustable foot support to carry the weight of the suction piping and inlet flange or gauge part pressure gauge tapings. Discharge pipe size of suction diffuser to be same size as pump inlet.
- C. Accessories: Adjustable foot support, blowdown tapping in bottom, gauge tapping in side.

## **2.06 PRESSURE-TEMPERATURE TEST PLUGS**

- A. Manufacturers:
  1. Peterson Equipment Company Inc: [www.petesplug.com/#sle](http://www.petesplug.com/#sle).
  2. Sisco Manufacturing Company Inc: [www.siscomfg.com/#sle](http://www.siscomfg.com/#sle).
- B. Construction: Brass body designed to receive temperature or pressure probe with removable protective cap, and Neoprene rated for minimum 200 degrees F.
- C. Application: Use extended length plugs to clear insulated piping.

## **2.07 BALANCING VALVES**

- A. Manufacturers:
  1. Armstrong International, Inc: [www.armstronginternational.com/#sle](http://www.armstronginternational.com/#sle).
  2. Ferguson Enterprises Inc: [www.fnw.com/#sle](http://www.fnw.com/#sle).
  3. Hays Fluid Controls: [www.haysfluidcontrols.com/#sle](http://www.haysfluidcontrols.com/#sle).
  4. Nexus Valve, Inc: [www.nexusvalve.com/#sle](http://www.nexusvalve.com/#sle).
  5. Oventrop Corporation; Hydrocontrol F: [www.ventrop.com/#sle](http://www.ventrop.com/#sle).
  6. Taco, Inc: [www.taco-hvac.com/#sle](http://www.taco-hvac.com/#sle).
  7. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Size 2 inch and Smaller:
  1. Provide style with flow balancing, flow measurement, and shut-off capabilities, memory stops, minimum of two metering ports and NPT threaded, soldered, or press connections.
  2. Metal construction materials consist of bronze or brass.
  3. Non-metal construction materials consist of Teflon, EPDM, or engineered resin.
- C. Size 2-1/2 inch and Larger:
  1. Provide butterfly style with integrated flow orifice or pitot style flow meter, shut-off capabilities, memory stops, and flanged or grooved connections.
  2. Valve body construction materials consist of cast iron, carbon steel, or ductile iron.
  3. Internal components construction materials consist of brass, aluminum bronze, bronze, Teflon, EPDM, NORYL, or engineered resin.

## **2.08 FLOW METERS**

- A. Manufacturers:

1. Dwyer Instruments, Inc: [www.dwyer-inst.com/#sle](http://www.dwyer-inst.com/#sle).
  2. EMCO Flow Systems: [www.emcoflow.com/#sle](http://www.emcoflow.com/#sle).
  3. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Direct reading with insert pitot tube, threaded coupling, for 150 psi working pressure, maximum 240 degrees F, 5 percent accuracy.
- C. Cast iron, wafer type, orifice insert flow meter for 250 psi working pressure, with read-out valves equipped with integral check valves with gasketed caps.

## **2.09 RELIEF VALVES**

- A. Manufacturers:
1. Apollo
  2. Armstrong
  3. ITT Bell & Gossett
- B. Bronze body, teflon seat, stainless steel stem and springs, automatic, direct pressure actuated, capacities ASME certified, labeled and factory set for 30 PSIG.

## **PART 3 EXECUTION**

### **3.01 INSTALLATION**

- A. Install specialties in accordance with manufacturer's instructions.
- B. Provide manual air vents at system high points and as indicated.
- C. For automatic air vents in ceiling spaces or other concealed locations, provide vent tubing to nearest drain.
- D. Provide air separator on suction side of system circulation pump and connect to expansion tank.
- E. Provide valved drain and hose connection on strainer blowdown connection.
- F. Provide pump suction fitting on suction side of base-mounted centrifugal pumps. Remove temporary strainers after cleaning systems.
- G. Support pump fittings with floor-mounted pipe and flange supports.
- H. Provide relief valves on pressure tanks, low-pressure side of reducing valves, heat exchangers, and expansion tanks.
- I. Pipe relief valve outlet to nearest floor drain.

## **END OF SECTION**

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## **SECTION 23 21 23 - HYDRONIC PUMPS**

### **PART 1 GENERAL**

#### **1.01 SECTION INCLUDES**

- A. In-line pumps.
- B. End-suction pumps.

#### **1.02 RELATED REQUIREMENTS**

- A. Section 03 30 00 - Cast-in-Place Concrete.
- B. Section 23 05 13 - Common Motor Requirements for HVAC Equipment.
- C. Section 23 09 23 - Direct-Digital Control System for HVAC.
- D. Section 23 09 34 - Variable-Frequency Motor Controllers for HVAC.

#### **1.03 REFERENCE STANDARDS**

- A. NFPA 70 - National Electrical Code.
- B. UL 778 - Standard for Motor-Operated Water Pumps.

#### **1.04 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide certified pump curves showing performance characteristics with pump and system operating point plotted. Include NPSH curve when applicable. Include electrical characteristics and connection requirements.
- C. Operation and Maintenance Data: Include installation instructions, assembly views, lubrication instructions, and replacement parts list.
- D. Maintenance Materials: Furnish the following for Owner's use in maintenance of project.
  - 1. See Section 01 60 00 - Product Requirements, for additional provisions.

#### **1.05 QUALITY ASSURANCE**

### **PART 2 PRODUCTS**

#### **2.01 MANUFACTURERS**

- A. Armstrong Fluid Technology, Inc: [www.armstrongfluidtechnology.com/#sle](http://www.armstrongfluidtechnology.com/#sle).
- B. Bell & Gossett, a Xylem Inc. brand: [www.bellgossett.com/#sle](http://www.bellgossett.com/#sle).
- C. Grundfos Pumps Corporation: [www.grundfos.com/#sle](http://www.grundfos.com/#sle).
- D. Wilo.
- E. Taco Comfort Solutions.
- F. Substitutions: See Section 01 60 00 - Product Requirements.

## **2.02 GENERAL**

- A. Provide pumps that operate at specified system fluid temperatures without vapor binding and cavitation, are non-overloading in parallel or individual operation, and operate within 25 percent of midpoint of published maximum efficiency curve.
- B. Electrical Requirements:
  - 1. Listed and classified by UL or testing agency acceptable to authority having jurisdiction as suitable for the purpose specified and indicated.
  - 2. Variable Frequency Drives (VFDs): Provide in accordance with Section 23 09 34, except for integral-VFDs.
  - 3. Enclosures: Provide unspecified product(s) required to fit motor:

## **2.03 IN-LINE PUMPS**

- A. Closed-Coupled, Single-Stage Pump: Vertical pump with radially- or horizontally-split casing; rated for discharge pressures up to 175 psi.
- B. Casing: Cast iron with seal flush connection, threaded suction, and discharge ports with gauge port and drain plug.
- C. Impeller: Bronze, fully enclosed, keyed directly to motor shaft or extension.
- D. Shaft: Carbon steel with stainless steel impeller cap screw or nut and bronze sleeve.
- E. Electrical:
  - 1. Motor: 1,750 rpm, open drip-proof (ODP); see Section 23 05 13.

## **2.04 END-SUCTION PUMPS**

- A. Split-Coupled Pump: Base-mounted, single-stage pump with horizontal shaft and radially- or horizontally-split casing rated for discharge pressures up to 175 psi.
- B. Casing: Cast iron or ductile iron with renewable bronze casing wearing rings, seal flush connection, drain plug, flanged suction, and discharge flanged connections with gauge ports.
- C. Impeller: Stainless steel, balanced, fully enclosed, keyed to shaft.
- D. Bearings: Oil lubricated roller or ball bearings.
- E. Shaft: Alloy steel with copper, bronze, or stainless steel shaft sleeve.
- F. Seal: Mechanical, 225 degrees F maximum continuous duty temperature.
- G. Drive: Flexible coupling with coupling guard.
- H. Baseplate: Cast iron or fabricated steel with integral drain rim.
- I. Electrical:
  - 1. Motor: 1,750 rpm, open drip-proof (ODP); see Section 23 05 13.
  - 2. Wiring Terminations: Provide terminal lugs to match branch circuit conductor quantities, sizes, and materials indicated. Enclose terminal lugs in terminal box sized to NFPA 70.

**PART 3 EXECUTION**

**3.01 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Provide access space around pumps for service. Provide no less than minimum space recommended by manufacturer.
- C. Decrease from line size with long radius reducing elbows or reducers. Support piping adjacent to pump such that no weight is carried on pump casings. For close-coupled or base-mounted pumps, provide supports under elbows on pump suction and discharge line sizes 4 inches and over.
- D. Provide line sized shut-off valve and pump suction fitting on pump suction, and line sized wafer check valve, shut off valve and flow meter on pump discharge.
- E. Install base-mounted pumps on concrete housekeeping base, with anchor bolts, set and level, and grout in place. See Section 03 30 00.
- F. Lubricate pumps before start-up.
- G. Controls: Interface each pump starter or VFD with HVAC controller; see Section 23 09 23.

**END OF SECTION**

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## **SECTION 23 31 00 - HVAC DUCTWORK**

### **PART 1 GENERAL**

#### **1.01 SECTION INCLUDES**

- A. Metal ducts.
- B. Flexible ducts to grilles, registers and diffusers.

#### **1.02 RELATED REQUIREMENTS**

- A. Section 23 07 13 - Duct Insulation: External insulation and duct liner.
- B. Section 23 33 00 - Air Duct Accessories.
- C. Section 23 36 00 - Air Terminal Units.

#### **1.03 REFERENCE STANDARDS**

- A. ASHRAE (FUND) - ASHRAE Handbook - Fundamentals.
- B. ASHRAE Std 126 - Method of Testing HVAC Air Ducts.
- C. ASTM A653/A653M - Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
- D. ICC (IMC) - International Mechanical Code.
- E. NFPA 90A - Standard for the Installation of Air-Conditioning and Ventilating Systems.
- F. SMACNA (DCS) - HVAC Duct Construction Standards Metal and Flexible.
- G. SMACNA (LEAK) - HVAC Air Duct Leakage Test Manual.
- H. SMACNA (RIDC) - Rectangular Industrial Duct Construction Standards.
- I. SMACNA (ROUND) - Round Industrial Duct Construction Standards.
- J. UL 181 - Standard for Factory-Made Air Ducts and Air Connectors.

#### **1.04 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide data for duct materials.
- C. Shop Drawings: Indicate duct fitting types, gauges, sizes, welds, and configuration.
- D. Project Record Documents: Record actual locations of ducts and duct fittings. Record changes in fitting location and type. Show additional fittings used.

#### **1.05 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacturing the type of products specified in this section, with minimum three years of documented experience, and approved by manufacturer.
- B. Installer Qualifications: Company specializing in performing the type of work specified in this section, with minimum three years of documented experience.

## **1.06 FIELD CONDITIONS**

- A. Do not install duct sealants when temperatures are less than those recommended by sealant manufacturers.
- B. Maintain temperatures within acceptable range during and after installation of duct sealants.

## **PART 2 PRODUCTS**

### **2.01 GENERAL REQUIREMENTS**

- A. Provide ductwork, fittings, hangers, supports, and appurtenances in accordance with NFPA 90A and SMACNA (DCS) guidelines unless stated otherwise.
- B. Provide metal duct unless otherwise indicated.
- C. Acoustical Treatment: Provide sound-absorbing liners and sectional silencers for metal-based ducts in compliance with Section 23 33 19.
- D. Duct Sealing and Leakage in accordance with Static Pressure Class:
- E. Duct Fabrication Requirements:
  - 1. Duct and Fitting Fabrication and Support: SMACNA (DCS) including specifics for continuously welded round and oval duct fittings.
  - 2. Use reinforced and sealed sheet-metal materials at recommended gauges for indicated operating pressures or pressure class.
  - 3. Construct tees, bends, and elbows with radius of not less than 1-1/2 times width of duct on centerline. Where not possible and where rectangular elbows must be used, provide turning vanes of perforated metal with glass fiber insulation.
  - 4. Provide turning vanes of perforated metal with glass fiber insulation when acoustical lining is indicated.
  - 5. Increase duct sizes gradually, not exceeding 15 degrees divergence wherever possible; maximum 30 degrees divergence upstream of equipment and 45 degrees convergence downstream.
  - 6. Provide turning vanes of perforated metal with glass fiber insulation when an acoustical lining is required.
  - 7. Where ducts are connected to exterior wall louvers and duct outlet is smaller than louver frame, provide blank-out panels sealing louver area around duct. Use same material as duct, painted black on exterior side; seal to louver frame and duct.

### **2.02 METAL DUCTS**

- A. Material Requirements:

1. Ductwork shall be minimum G-60 coated galvanized steel of lock forming grade conforming to ASTM Standards A-525 and A-527. Duct wall thicknesses, reinforcements, seams, joints, sealing, cross bracing, beading, hangers, supports, etc., shall be in accordance with the latest manual of heating, ventilating and air conditioning duct construction standards as published by the Sheet Metal and Air Conditioning Contractors National Assoc., Inc. (SMACNA).
- B. Pressure Class:
1. All exhaust air, return air, fresh air, transfer air and mixing plenum ductwork shall be 2" pressure class.
  2. All supply air ductwork systems that do not utilize variable air volume boxes shall be 2" pressure class.
  3. All supply air ductwork upstream of variable air volume boxes shall be 6" pressure class.
  4. All supply air ductwork downstream of variable air volume boxes shall be 2" pressure class.
- C. Low and Medium Pressure Round Ductwork:
1. United Sheet Metal Co., Semco Carrier, Linx Industries Lindab Safe, Greater Wisconsin Sheet Metal, Eastern Sheet Metal, Pressure Airduct Corp. Sheet Metal Connectors, or Stamped Fittings, Inc.
  2. Round helically wound lock seam zinc coated steel conduit.
  3. All fittings shall be minimum 20-gauge zinc coated steel.
  4. All 45 deg. elbows shall have a minimum of 3 sections and all 90 deg. elbows shall have a minimum of 5 sections. Smooth long sweep die formed fittings are preferred.
  5. Branch ductwork take-offs shall be accomplished with a 90 deg. shoe tap saddle with an increased area connection.
  6. All elbows shall be distortion free.
  7. All fittings and joints to be joined using United Duct Sealer or Linx Industries Lindab Safe self-sealing system, in accordance with manufacturers recommendations.

### **2.03 FLEXIBLE DUCTS TO GRILLES, REGISTERS AND DIFFUSERS**

- A. Furnish and install flexible ducts where indicated on the drawings.
- B. Flexmaster, Novaflex, Thermaflex, or Buckley flexible ductwork.
- C. Factory applied glass fiber insulation with vaporproof jacket, minimum total insulating value R=6.
- D. The ductwork shall be UL 181 listed, Class 1 Air Duct and comply with NFPA 90A and 90B.
- E. Supply, Return, and Exhaust Ducts:
  1. Flexmaster Type 1, Novaflex Type 8, Thermaflex M-KC, or Buckley Type 3.
  2. Polyethylene fabric core supported by a galvanized steel helix formed and mechanically locked to the liner.

3. Working pressure not less than 10" w.g. positive and 2" w.g. negative.
4. Minimum Acoustic Performance:

|                   | 125 Hz | 250 Hz | 500 Hz | 1000 Hz | 2000 Hz |
|-------------------|--------|--------|--------|---------|---------|
| Up to 8 inch dia. | 5      | 10     | 22     | 34      | 22      |
| 10 -12 inch dia.  | 6      | 27     | 22     | 28      | 18      |

F. Transfer Ducts:

1. Flexmaster Type 6M, Novaflex Type 6, Thermaflex M-KE, or Buckley Type 4.
2. Acoustical spun bond nylon fabric core supported by a galvanized steel helix formed and mechanically locked to the liner.
3. Working pressure not less than 6" w.g. positive.
4. Minimum Acoustic Performance:

|                   | 125 Hz | 250 Hz | 500 Hz | 1000 Hz | 2000 Hz |
|-------------------|--------|--------|--------|---------|---------|
| Up to 8 inch dia. | 26     | 27     | 27     | 31      | 32      |
| 10 -12 inch dia.  | 22     | 26     | 24     | 31      | 31      |

### **PART 3 EXECUTION**

#### **3.01 INSTALLATION**

- A. Verify dimensions at the site, making field measurements and drawings necessary for fabrication and erection. Check plans showing work of other trades and consult with Engineer in the event of any interference.
- B. Make allowances for beams, pipes or other obstructions in building construction and for work of other contractors. Transform, divide or offset ducts as required, in accordance with SMACNA, except do not reduce duct to less than six inches in any dimension and do not exceed a 6:1 aspect ratio.
- C. Cut or drill test holes in ducts where indicated or as required. Cap with neoprene plugs.
- D. Provide frames constructed of angles or channels for coils, filters, dampers or other devices installed in duct systems, and make all connections to such equipment, including equipment furnished by others. Secure frames with gaskets and screws or nut, bolts and washers.
- E. For all ductwork upstream of the variable volume air boxes, all indoor transverse joints, longitudinal seams, girth joints, branch intersections, fitting subsections, lower connections, grilles, registers and outlets connections, access door frame connections, etc., are to be sealed in accordance with IECC Seal Class A requirements for all low, medium and high pressure ductwork, utilizing Hardcast Inc. Iron Grip 601 water based UL classified vinyl acrylic duct sealant. Clean all surfaces of dirt, oil and grease before application. Coverage to be approximately 125 square feet per gallon with 20 mil thick wet film. At Contractor's option, duct sealing may be performed utilizing Aero seal duct sealing system in lieu of vinyl acrylic duct sealant.

- F. Seal water tight with G.E. Silicone Construction Sealant all joints within 6" of bottom of all outside air intake ducts and pitch outside air intakes to outside of building.
- G. Seal water tight with G.E. Silicone Construction Sealant all joints within 6" of bottom of all exhaust ductwork from outside termination back to automatic exhaust dampers and/or backdraft dampers.
- H. Furnish and install a drip pan in exhaust and relief ductwork under each roof exhauster and weatherproof hood per plan detail. Seal water tight with G.E. Silicone Construction Sealant all joints in drip pan and all joints within 6" of bottom of drip pan.
- I. Duct sizes indicated are precise inside dimensions. For lined ducts, maintain sizes inside lining.
- J. Locate ducts with sufficient space around equipment to allow normal operating and maintenance activities.
- K. For flexible ductwork to grilles, registers and diffusers:
  - 1. Flexible duct may be used for final connection to grilles, registers and diffusers where indicated. Where flexible duct is used, it shall be the minimum length required to make the final connections, but no greater than 4 feet in length. Flexible ducts shall be as straight as possible with no more than one 90 deg. elbow.
  - 2. Individual sections of flexible ductwork shall be of one piece construction. Splicing of short sections will not be accepted.
  - 3. Penetration of any partition, wall, or floor with flexible duct will not be accepted.
  - 4. Fittings, couplings, etc., shall be joined by applying a coat of 3M EC-800 or Benjamin Foster 30-02 cement to the joining surfaces. Insert fitting to the bead and secure with a metal draw band. Finally, wrap exposed seam with a 3" wide band of pressure sensitive duct tape.
  - 5. Ducts shall be hung from the building construction with galvanized steel strap hangers.

**END OF SECTION**

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**SECTION 23 33 00 - AIR DUCT ACCESSORIES**

**PART 1 GENERAL**

**1.01 SECTION INCLUDES**

- A. Air turning devices/extractors.
- B. Duct access doors.
- C. Duct test holes.
- D. Flexible duct connectors to air handling equipment.
- E. Volume control dampers.

**1.02 REFERENCE STANDARDS**

- A. NFPA 90A - Standard for the Installation of Air-Conditioning and Ventilating Systems.
- B. NFPA 96 - Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.
- C. SMACNA (DCS) - HVAC Duct Construction Standards Metal and Flexible.

**1.03 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide for shop-fabricated assemblies including volume control dampers, duct access doors, duct test holes, and hardware used. Include electrical characteristics and connection requirements.
- C. Shop Drawings: Indicate for shop fabricated assemblies including volume control dampers.
- D. Project Record Drawings: Record actual locations of access doors and test holes.

**1.04 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacturing the type of products specified in this section, with minimum three years of documented experience.

**1.05 DELIVERY, STORAGE, AND HANDLING**

- A. Protect dampers from damage to operating linkages and blades.

**PART 2 PRODUCTS**

**2.01 AIR TURNING DEVICES/EXTRACTORS**

- A. Multi-blade device with blades aligned in short dimension; steel construction; with individually adjustable blades, mounting straps.

**2.02 DUCT ACCESS DOORS**

- A. Fabrication: Rigid and close fitting of galvanized steel with sealing gaskets and quick-fastening locking devices. For insulated ducts, install minimum 1-inch thick insulation with sheet metal cover.
  - 1. Less Than 12 inches Square: Secure with sash locks.

2. Up to 18 inches Square: Provide two hinges and two sash locks.
3. Up to 24 by 48 inches: Three hinges and two compression latches with outside and inside handles.

### **2.03 DUCT TEST HOLES**

- A. Temporary Test Holes: Cut or drill in ducts as required. Cap with neoprene plugs, threaded plugs, or threaded or twist-on metal caps.

### **2.04 FLEXIBLE DUCT CONNECTORS TO AIR HANDLING EQUIPMENT**

- A. Fabricate in accordance with SMACNA (DCS) and as indicated.
- B. Flexible Duct Connections: Fabric crimped into metal edging strip.
  1. Fabric: UL listed fire-retardant neoprene coated woven glass fiber fabric to NFPA 90A, minimum density 30 oz/sq yd.
- C. Maximum Installed Length: 14 inch.

### **2.05 VOLUME CONTROL DAMPERS**

- A. Fabricate in accordance with SMACNA (DCS) and as indicated.
- B. Splitter Dampers:
  1. Material: Same gauge as duct to 24 inches size in either direction, and two gauges heavier for sizes over 24 inches.
  2. Blade: Fabricate of single thickness sheet metal to streamline shape, secured with continuous hinge or rod.
  3. Operator: Minimum 1/4 inch diameter rod in self aligning, universal joint action, flanged bushing with set screw.
- C. Single Blade Dampers:
  1. Fabricate for duct sizes up to 6 by 30 inch.
  2. Blade: 24 gauge, 0.0239 inch, minimum.
- D. Multi-Blade Damper: Fabricate consisting of opposed blades with maximum blade sizes 8 by 72 inches. Assemble center- and edge-crimped blades in prime-coated or galvanized-channel frame with suitable hardware.
  1. Blade: 18 gauge, 0.0478 inch, minimum.
- E. End Bearings: Except in round ducts 12 inches and smaller, provide end bearings. On multiple blade dampers, provide oil-impregnated nylon, thermoplastic elastomer, or sintered bronze bearings.

## **PART 3 EXECUTION**

### **3.01 INSTALLATION**

- A. Install accessories in accordance with manufacturer's instructions, NFPA 90A, and follow SMACNA (DCS). See Section 23 31 00 for duct construction and pressure class.

- B. Provide duct access doors for inspection and cleaning before and after filters, coils, fans, automatic dampers, at fire dampers, combination fire and smoke dampers, and elsewhere as indicated. Provide for cleaning kitchen exhaust ducts in accordance with NFPA 96 Provide minimum 8 by 8 inch size access door for hand and shoulder access, or as indicated on drawings. Provide minimum 4 by 4 inch size access door for balancing dampers only. Review locations prior to fabrication.
- C. Provide duct test holes where indicated and required for testing and balancing purposes.
- D. Provide balancing dampers at points on supply, return, and exhaust systems where branches are taken from larger ducts as required for air balancing. Install minimum two duct widths from duct take-off.
- E. Provide balancing dampers on duct take-off to diffusers, grilles, and registers, regardless of whether dampers are specified as part of the diffuser, grille, or register assembly.
- F. Install air measuring station at locations indicated on the drawings in accordance with manufacturers recommendations.

**END OF SECTION**

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## **SECTION 23 34 23 - HVAC FANS**

### **PART 1 GENERAL**

#### **1.01 SECTION INCLUDES**

- A. Roof exhausters.
- B. Inline centrifugal fans.
- C. Utility vent blowers.

#### **1.02 RELATED REQUIREMENTS**

- A. Section 23 05 13 - Common Motor Requirements for HVAC Equipment.
- B. Section 23 31 00 - HVAC Ductwork.

#### **1.03 REFERENCE STANDARDS**

- A. AMCA 99 - Standards Handbook.

#### **1.04 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide data on fans and accessories, including fan curves with specified operating point plotted, power, rpm, sound power levels at rated capacity, and electrical characteristics and connection requirements.
- C. Manufacturer's Instructions: Indicate installation instructions.
- D. Maintenance Data: Include instructions for lubrication, motor and drive replacement, spare parts list, and wiring diagrams.

#### **1.05 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacturing the type of products specified in this section, with minimum three years of documented experience.

### **PART 2 PRODUCTS**

#### **2.01 HVAC FANS - GENERAL**

- A. Static and Dynamically Balanced: Comply with AMCA 204.
- B. Performance Ratings: Comply with AMCA 210, bearing certified rating seal.
- C. Sound Ratings: Comply with AMCA 301, tested to AMCA 300, bearing certified sound ratings seal.
- D. Fabrication: Comply with AMCA 99.
- E. Electrical Components: Listed and classified by Underwriters Laboratories Inc. as suitable for the purpose specified and indicated.

#### **2.02 ROOF EXHAUST FANS**

- A. Manufacturers:
  - 1. Carnes

2. Greenheck
  3. PennBarry, Division of Air System Components: [www.pennbarry.com/#sle](http://www.pennbarry.com/#sle).
  4. Twin City Fan & Blower: [www.tcf.com/#sle](http://www.tcf.com/#sle).
  5. Cook
  6. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Fan Unit: V-belt as indicated, with spun aluminum housing; resilient mounted motor; 1/2 inch mesh, 0.62 inch thick aluminum wire birdscreen; square base to suit roof curb with continuous curb gaskets.
- C. Roof Curb: 18 inch high self-flashing of galvanized steel with continuously welded seams, insulation and curb bottom.
- D. Disconnect Switch: Factory wired, nonfusible, in housing for thermal overload protected motor.
- E. Backdraft Damper: Gravity actuated, aluminum multiple blade construction, felt edged with offset hinge pin, nylon bearings, blades linked, and line voltage motor drive, power open, spring return.
- F. Sheaves: Cast iron or steel, dynamically balanced, bored to fit shafts and keyed; variable and adjustable pitch motor sheave selected so required rpm gets attained with sheaves set at mid-position; fan shaft with self-aligning pre-lubricated ball bearings.

### **2.03 INLINE EXHAUST FANS**

- A. Manufacturers:
1. Greenheck
  2. Cook
  3. Carnes
  4. PennBarry, Division of Air System Components: [www.pennbarry.com/#sle](http://www.pennbarry.com/#sle).
  5. Twin City Fan & Blower: [www.tcf.com/#sle](http://www.tcf.com/#sle).
  6. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Furnish fans of steel or aluminum construction with universal type mounting bracket, centrifugal fan wheel with ball bearing supports, variable speed EC motor (RF-3, EF-1 and EF-3) and NEMA approved ball bearing motor (RF-1) as indicated, adjustable V-belt drive or direct connected as indicated, adjustable motor base for V-belt drive units, vibration isolators and bearing lubrication tubes.
- C. For all direct drive EC motors, furnish with factory pre-wired potentiometer for balancing.
- D. Sheaves: Cast iron or steel, dynamically balanced, bored to fit shafts and keyed; variable and adjustable pitch motor sheaves selected so required rpm gets reached with sheaves set at mid-position; fan shaft with self-aligning prelubricated ball bearings.

### **2.04 UTILITY EXHAUST FANS**

- A. Manufacturers:

1. Greenheck
  2. Cook
  3. PennBarry, Division of Air System Components: [www.pennbarry.com/#sle](http://www.pennbarry.com/#sle).
  4. Carnes
  5. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Furnish fans with forward curved, backwardly inclined centrifugal fan wheel with ball bearing supports, NEMA approved resiliently mounted open ball bearing motor with adjustable motor mount, direct drive, vibration isolation and steel fan housing. Furnish cover over motor and drive, and bonderized prime coat or galvanized finish.
- C. Motorized multi-louver discharge damper with low voltage electric damper operator.

### **PART 3 EXECUTION**

#### **3.01 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Install all fans where indicated on the drawings and in accordance with manufacturers recommendations. Secure roof exhausters with stainless steel lag screws to roof curb.
- C. Roof mounted Centrifugal fans shall be set on Pate, Thy or Vent Products equipment support curbs complete with minimum 18 gauge galvanized steel construction with integral base plate, continuous welded corner seams, factory installed wood nailer, counter flashing with lag screws and built in cant for roof as required.
- D. Utility set exhaust fan EF-2 shall be installed on equipment support rails. Support rails shall be securely fastened to existing structure.
- E. All suspended fans shall be supported from steel supports with suspensions, frames, brackets, braces, etc. Supports shall be constructed to properly support and distribute the load and shall incorporate anti-vibration devices, anti-sway bracing and anchoring plates as required. Supports may be constructed of I-beams, channels, angle iron or threaded steel rods. All permanent supports shall be welded. All threaded rods and bolts shall have nuts welded to rod, threads peened or double nuts.
- F. All floor interior mounted fans shall be set on concrete pads which shall be a minimum of 3 ½" thick unless otherwise indicated. Pads shall be sized for a minimum overlap of 3" on the exterior dimension of the fan base mounted thereon.
- G. Extend ducts to roof exhausters into roof curb. Counterflash duct to roof opening.
- H. Provide sheaves required for final air balance.
- I. Install backdraft dampers on inlet to roof exhausters.

### **END OF SECTION**

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**SECTION 23 36 00 - AIR TERMINAL UNITS**

**PART 1 GENERAL**

**1.01 RELATED REQUIREMENTS**

- A. Section 23 31 00 - HVAC Ductwork.

**1.02 REFERENCE STANDARDS**

- A. AHRI 410 - Forced-Circulation Air-Cooling and Air-Heating Coils.
- B. AHRI 880 (I-P) - Performance Rating of Air Terminals.
- C. ASTM C1071 - Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material).
- D. NFPA 90A - Standard for the Installation of Air-Conditioning and Ventilating Systems.
- E. SMACNA (SRM) - Seismic Restraint Manual Guidelines for Mechanical Systems.

**1.03 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide data indicating configuration, general assembly, and materials used in fabrication. Include catalog performance ratings that indicate airflow, static pressure, and NC designation. Include electrical characteristics and connection requirements.
- C. Shop Drawings: Indicate configuration, general assembly, and materials used in fabrication, and electrical characteristics and connection requirements.
- D. Certificates: Certify that coils are tested and rated in accordance with AHRI 410.
- E. Manufacturer's Installation Instructions: Indicate support and hanging details, installation instructions, recommendations, and service clearances required.
- F. Operation and Maintenance Data: Include manufacturer's descriptive literature, operating instructions, maintenance and repair data, and parts lists. Include directions for resetting constant-volume regulators.
- G. Warranty: Submit manufacturer warranty and ensure forms have been completed in Owner's name and registered with manufacturer.
- H. Maintenance Materials: Furnish the following for Owner's use in maintenance of project.
  - 1. See Section 01 60 00 - Product Requirements for additional provisions.

**1.04 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacturing the type of products specified in this section, with minimum three years of documented experience.

**1.05 WARRANTY**

- A. See Section 01 78 00 - Closeout Submittals for additional warranty requirements.
- B. Provide five year manufacturer warranty for air terminal units.

## **PART 2 PRODUCTS**

### **2.01 SINGLE-DUCT, VARIABLE-VOLUME UNITS**

- A. Manufacturers:
  - 1. Krueger
  - 2. Metalaire
  - 3. Price
- B. General:
  - 1. Factory-assembled, AHRI 880 (I-P) rated, air volume control terminal with damper assembly, flow sensor, externally mounted volume controller, duct collars, and all required features.
  - 2. Control box bearing identification, including but not necessarily limited to nominal cfm, maximum and minimum factory-set airflow limits, coil type and coil (right or left hand) connection, where applicable.
- C. Unit Casing:
  - 1. Minimum 22 gauge, 0.0299 inch galvanized steel.
  - 2. Air Inlet Collar: Provide round, suitable for standard flexible duct sizes.
  - 3. Unit Discharge: Rectangular, with slip-and-drive connections.
  - 4. Acceptable Liners:
    - a. 1/2 inch thick, coated, fibrous-glass complying with ASTM C1071.
      - 1) Secure with adhesive.
      - 2) Coat edges exposed to airstream with NFPA 90A approved sealant.
      - 3) Cover liner with non-porous foil.
    - b. Liner not to contain pentabrominated diphenyl ether (CAS #32534-81-9) or octabrominated diphenyl ether.
- D. Damper Assembly:
  - 1. Heavy-gauge, galvanized steel, or extruded aluminum construction with solid steel, nickel-plated shaft pivoting on HDPE, self-lubricating bearings.
  - 2. Provide integral position indicator or alternative method for indicating damper position over full range of 90 degrees.
  - 3. Incorporate low leak damper blades for tight airflow shutoff.
- E. Hot Water Heating Coil:
  - 1. Coil Casing: Minimum 22 gauge, 0.0299 inch galvanized steel, factory-installed on terminal discharge with rectangular outlet, duct connection type.
    - a. Access Door: Gasketed and insulated located on bottom.

2. Coil Fins: Aluminum or aluminum plated fins, mechanically-bonded to seamless copper tubes.
3. Coil leak tested to minimum 350 psig.
4. Base performance data on tests run in accordance with AHRI 410 and units to bear AHRI 410 label.
5. VAV box selections for shop drawing review shall be made by fixing the design flow rates (gpm) to the scheduled values. Leaving air temperatures shall meet or exceed the scheduled values.

### **PART 3 EXECUTION**

#### **3.01 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Install the inlets of air terminal units and air flow sensors a minimum of four duct diameters from elbows, transitions, and duct takeoffs.
- C. Provide ceiling access doors or locate units above easily removable ceiling components.
- D. Support units individually from structure in accordance with SMACNA (SRM).
- E. Do not support from ductwork.
- F. Connect to ductwork in accordance with Section 23 31 00.

#### **3.02 ADJUSTING**

- A. Reset volume with damper operator attached to assembly allowing flow range modulation from 100 percent of design flow to zero percent full flow. Set units with heating coils for minimum zero percent full flow.

#### **3.03 CLEANING**

- A. Vacuum clean coils and inside of units.

#### **3.04 CLOSEOUT ACTIVITIES**

- A. See Section 01 78 00 - Closeout Submittals for closeout submittals.
- B. See Section 01 79 00 - Demonstration and Training for additional requirements.

### **END OF SECTION**

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## **SECTION 23 37 00 - AIR OUTLETS AND INLETS**

### **PART 1 GENERAL**

#### **1.01 REFERENCE STANDARDS**

- A. ASHRAE Std 70 - Method of Testing the Performance of Air Outlets and Air Inlets.
- B. SMACNA (ASMM) - Architectural Sheet Metal Manual.

#### **1.02 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide data for equipment required for this project. Review outlets and inlets as to size, finish, and type of mounting prior to submission. Submit schedule of outlets and inlets showing type, size, location, application, and noise level.

#### **1.03 QUALITY ASSURANCE**

- A. Test and rate air outlet and inlet performance in accordance with ASHRAE Std 70.
- B. Test and rate louver performance in accordance with AMCA 500-L.
- C. Manufacturer Qualifications: Company specializing in manufacturing the type of products specified in this section, with minimum three years of documented experience.

### **PART 2 PRODUCTS**

#### **2.01 MANUFACTURERS**

- A. Krueger
- B. Price
- C. Titus

#### **2.02 SQUARE PLAQ CEILING DIFFUSERS**

- A. Type: Provide square formed core removable ceiling diffusers constructed to maintain 360 degree discharge air pattern.
- B. Connections: As indicated on drawings.
- C. Frame: Provide inverted T-bar type.
- D. Fabrication: Steel with baked enamel finish.
- E. Color: As selected by Architect from manufacturer's standard range.
- F. Accessories: Provide removable core with damper adjustable from diffuser face.

#### **2.03 CEILING EGG CRATE EXHAUST, RETURN AND TRANSFER GRILLES**

- A. Type: Egg crate style face consisting of 1/2 by 1/2 by 1/2 inch grid core.
- B. Fabrication: Grid core consists of aluminum with baked enamel finish.
- C. Color: To be selected by Architect from manufacturer's standard range.
- D. Frame: Grilles for T-bar lay-in installation shall have no flange border. Surface mounted type to have flange type frame with countersunk holes for surface mounting.

## **2.04 WALL SUPPLY GRILLES**

- A. Furnish grilles with adjustable double deflection steel grille core, flanged frame with sponge rubber gasket, horizontal face fins with 3/4" maximum fin spacing and vertical rear fins.
- B. Frame: 1 inch margin with countersunk screw mounting and gasket.
- C. Fabrication: Steel with 20 gauge, 0.0359 inch minimum frames and 22 gauge, 0.0299 inch minimum blades, steel and aluminum with 20 gauge, 0.0359 inch minimum frame, or aluminum extrusions, with factory baked enamel finish.
- D. Color: To be selected by Architect from manufacturer's standard range.

## **2.05 WALL EXHAUST AND RETURN GRILLES**

- A. Furnish registers with steel grille core, flanged frame with sponge rubber gasket, fixed horizontal face fins with a 3/4" maximum fin spacing set in an angular position and a key operated opposed blade volume damper.
- B. Frame: 1 inch margin with countersunk screw mounting.
- C. Color: To be selected by Architect from manufacturer's standard range.

## **2.06 LOUVERS**

- A. See Specification Section 08 91 00 - Louvers

## **PART 3 EXECUTION**

### **3.01 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Comply with SMACNA (ASMM) for flashing/counter-flashing of roof penetrations and supports for roof curbs and roof mounted equipment.
- C. Check location of outlets and inlets and make necessary adjustments in position to comply with architectural features, symmetry, and lighting arrangement.
- D. Install diffusers to ductwork with air tight connection.
- E. Provide balancing dampers on duct take-off to diffusers and grilles and registers, despite whether dampers are specified as part of diffuser, or grille and register assembly.
- F. Paint ductwork visible behind air outlets and inlets matte black.
- G. Where ceiling tiles are cut to accomodate grilles, coordinate with General Contractor the painting of cut edge to match color of ceiling tile.
- H. Install insulated metal panel on unused portion of louver. Panels must be sealed weathertight to louver assembly with flashing as required for proper drainage to outside of building.

### **3.02 CLOSEOUT ACTIVITIES**

- A. Demonstrate operational system to Owner's representative.
- B. Instruct Owner's representative to maintain system and use occupant controls or interfaces, as required.

**3.03 PROTECTION**

- A. Protect installed products until completion of project.
- B. Replace, repair, or touch-up damaged products before Substantial Completion.

**END OF SECTION**

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## **SECTION 23 73 13 - INDOOR AIR-HANDLING UNITS**

### **PART 1 GENERAL**

#### **1.01 REFERENCE STANDARDS**

- A. AHRI 410 - Forced-Circulation Air-Cooling and Air-Heating Coils.
- B. ASHRAE Std 62.1 - Ventilation for Acceptable Indoor Air Quality.
- C. ASHRAE Std 135 - A Data Communication Protocol for Building Automation and Control Networks.
- D. NFPA 70 - National Electrical Code.
- E. NFPA 90A - Standard for the Installation of Air-Conditioning and Ventilating Systems.
- F. UL (DIR) - Online Certifications Directory.

#### **1.02 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data:
  - 1. Published Literature: Indicate dimensions, weights, capacities, ratings, gauges and finishes of materials, and electrical characteristics and connection requirements.
  - 2. Filters: Data for filter media, filter performance data, filter assembly, and filter frames.
  - 3. Fans: Performance and fan curves with specified operating point clearly plotted, power, RPM.
  - 4. Sound Power Level Data: Fan outlet and casing radiation at rated capacity.
  - 5. Electrical Requirements: Power supply wiring including wiring diagrams for interlock and control wiring, clearly indicating factory-installed and field-installed wiring.
- C. Shop Drawings: Indicate assembly, unit dimensions, weight loading, required clearances, construction details, field connection details, and electrical characteristics and connection requirements.
- D. Executed Warranty: Submit documentation of final executed warranty completed in Owner's name and registered with manufacturer.
- E. Manufacturer's Instructions: Include installation instructions.
- F. Maintenance Data: Include instructions for lubrication, filter replacement, motor and drive replacement, spare parts lists, and wiring diagrams.
- G. Maintenance Materials: Furnish the following for Owner's use in maintenance of project.
  - 1. See Section 01 60 00 - Product Requirements for additional provisions.
  - 2. Extra Filters: One set for each unit.

#### **1.03 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacturing the type of products specified in this section, with minimum three years of documented experience.

#### **1.04 DELIVERY, STORAGE, AND HANDLING**

- A. Accept products on site in factory-fabricated protective containers, with factory-installed shipping skids and lifting lugs. Inspect for damage.
- B. Store in clean dry place and protect from weather and construction traffic. Handle carefully to avoid damage to components, enclosures, and finish.
- C. Do not operate units until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.

#### **1.05 WARRANTY**

- A. See Section 01 78 00 - Closeout Submittals for additional warranty requirements.
- B. Provide minimum one year manufacturer warranty covering repair or replacement due to defective materials or workmanship.

### **PART 2 PRODUCTS**

#### **2.01 MANUFACTURERS**

- A. Daikin Applied
- B. Aeon
- C. Trane Technologies
- D. JCI/York
- E. PACE

#### **2.02 REGULATORY REQUIREMENTS**

- A. Products Requiring Electrical Connection: Listed and classified by UL (DIR) as suitable for the purpose specified and indicated.

#### **2.03 CONSTRUCTION**

- A. Furnish sectionalized double wall casing of insulated steel with bonderized paint or galvanized steel finish, base rails and all necessary access panels to service fan bearings, coils and dampers. Complete with insulated waterproofed drain pan. Furnish blank sections as indicated or required to provide service access.
- B. Base rail shall be of sufficient height to raise unit for external trapping of condensate drain pans.
- C. Variable aspect ratio as required to meet dimensional requirements as scheduled.
- D. Provide coils with a maximum fin spacing of 14 fins per inch.
- E. Drainable hot water coil constructed of copper tubes, aluminum fins and 3-way valve (where specified on plans).
- F. Standard single serpentine drainable chilled water coil constructed of copper tubes and aluminum fins as indicated.
- G. Furnish flat arrangement 1" thick low velocity throwaway MERV 8 pre-filters.

- H. Furnish an angle or flat arrangement with 2" thick low velocity throwaway MERV 13 final filters.
- I. Furnish filter draft gauge with 0" to 2" H2O range scale.
- J. Disconnect shall be pre-wired.
- K. Airflow monitoring stations.
- L. Duct mounted smoke detector.

#### **2.04 FAN SECTION (AHU-1)**

- A. Air foil, single width, single inlet, centrifugal plug fan, in accordance with AMCA 99.
- B. Where multiple fans are scheduled, provide direct drive fan plenum fan system with variable speed EC motors or VFD rated motors. Provide a VFD for each motor or independent motor controls factory wired to the fan array manufacturer's controller with single point electrical connection
- C. Provide fan array control package with the following minimum controls:
  - 1. Bacnet integration
  - 2. Airflow measurement per fan output to the BAS as a single airflow signal utilizing piezometer rings on each fan inlet with differential pressure transmitters.
  - 3. Alarm of individual fan failure.
  - 4. Operator interface touch screen at the control panel. Individual motor circuit protection.
  - 5. Indicator lights for status of each fan.
- D. Performance Ratings: Determined in accordance with AMCA 210 and labeled with AMCA Certified Rating Seal.
- E. Sound Ratings: AMCA 301; tested to AMCA 300 and label with AMCA Certified Sound Rating Seal.
- F. Bearings: Self-aligning, grease lubricated, with lubrication fittings extended to exterior of casing with copper tube and grease fitting rigidly attached to casing. Minimum L-10 life of 40,000 hours at maximum rated speed.
- G. Mounting:
  - 1. Individual fan units:
    - a. Locate fan and motor internally on welded steel base coated with corrosion resistant paint.
    - b. Factory mount motor on slide rails.
    - c. Provide access to motor, drive, and bearings through removable casing panels or hinged access doors.
    - d. Provide channel frame for installation of manual blank-off panel. Provide one panel.
- H. Fan Array Units:
  - 1. Mount fan module structural housing and panel assembled within AHU section with blank off panel sealing to casing.
- I. External Motor Junction Box:

1. Factory mount NEMA 4 external junction box and connect to extended motor leads from internally mounted motors.
- J. Motor Wiring Conduit:
  1. Factory wire fan motor wiring to the unit mounted starter-disconnect, variable frequency drive, and external motor junction box. Provide each motor with a VFD.

## **2.05 FAN SECTION (AHU-2)**

- A. Plenum airfoil centrifugal wheel with ball bearing supports, grease bearing extensions, NEMA approved resiliently mounted open ball bearing motor with adjustable motor mount, direct drive and vibration isolation.
- B. Fan diameter and speed as required such that the setpoint of the variable frequency drive does not exceed 65 Hz to meet the scheduled design parameters.

## **2.06 COIL SECTION**

- A. Casing: Provide access to both sides of coils. Enclose coils with headers and return bends fully contained within casing. Slide coils into casing through removable end panel with blank off sheets and sealing collars at connection penetrations.
- B. Drain Pans: 24 inch downstream of coil and down spouts for cooling coil banks more than one coil high.
- C. Air Coils:
  1. Certify capacities, pressure drops, and selection procedures in accordance with AHRI 410.
- D. Fabrication:
  1. Tubes: 5/8 inch OD seamless copper expanded into fins, brazed joints.
  2. Fins: Aluminum.
  3. Casing: Die formed channel frame of galvanized steel.
- E. Water Cooling Coils:
  1. Headers: Cast iron, seamless copper tube, or prime coated steel pipe with brazed joints.
  2. Configuration: Drainable, with threaded plugs for drain and vent; threaded plugs in return bends and in headers opposite each tube.

## **PART 3 EXECUTION**

### **3.01 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Install units where indicated on plans.
- C. Units will require disassembly for ingress to the mechanical room. The Mechanical Contractor shall coordinate disassembly and reassembly requirements with the unit manufacturer to ensure that the unit manufacturer's warranty remains intact.

- D. Furnish and install all equipment supports as indicated or required for the installation of units, including miscellaneous upper steel as required to frame into overhead construction for distribution of weight.
- E. Floor mounted units shall be set on concrete pads unless indicated otherwise. Concrete pads shall be a minimum of 3-1/2" thick and shall be sized for a minimum overlap of 3" on the exterior dimension of the unit mounted thereon.
- F. Contractor shall check the plans and verify the proposed unit can be installed in the space allotted and still have adequate room for servicing. All piping and/or duct modifications required for installation of the unit shall be the responsibility of the Mechanical Contractor.
- G. Hot water coils shall be fitted with manual air vent assemblies at the top of each header and for each return bend header. Vent pipes shall extend through the exterior of the unit casing and each shall be complete with manual air vents.
- H. Hot water coils shall be fitted with drain piping at each header and for each return bend header. All drain pipes shall extend through the exterior of the unit casing and shall be fitted with full size drain valves with male hose bibb fitting.
- I. Install flexible duct connections between fan inlet and discharge ductwork and air handling unit sections. Ensure that metal bands of connectors are parallel with minimum 1 inch flex between ductwork and fan while running.
- J. Make connections to coils with unions or flanges.
- K. Hydronic Coils:
  - 1. Hydronic Coils: Connect water supply to leaving air side of coil (counterflow arrangement).
  - 2. Provide shut-off valve on supply line and lockshield balancing valve with memory stop on return line.
  - 3. Locate water supply at bottom of supply header and return water connection at top.
  - 4. Provide manual air vents at high points complete with stop valve.
  - 5. Ensure water coils are drainable and provide drain connection at low points.
- L. Cooling Coils:
  - 1. Pipe drain and overflow to nearest floor drain.

### **3.02 SYSTEM STARTUP**

- A. Provide manufacturer's field representative to perform systems startup.

### **3.03 CLOSEOUT ACTIVITIES**

- A. See Section 01 78 00 - Closeout Submittals for closeout submittals.
- B. Demonstration: Demonstrate operation of system to Owner's personnel.
  - 1. Use operation and maintenance data as reference during demonstration.
  - 2. Briefly describe function, operation, and maintenance of each component.

- C. Training: Train Owner's personnel on operation and maintenance of system.
  - 1. Use operation and maintenance manual as training reference, supplemented with additional training materials as required.
  - 2. Provide minimum of two hours of training.
  - 3. Instructor: Manufacturer's training personnel.
  - 4. Location: At project site.

**END OF SECTION**

## **SECTION 23 73 23 - OUTDOOR AIR-HANDLING UNITS**

### **PART 1 GENERAL**

#### **1.01 REFERENCE STANDARDS**

- A. AHRI 410 - Forced-Circulation Air-Cooling and Air-Heating Coils.
- B. AMCA 500-D - Laboratory Methods of Testing Dampers for Rating.
- C. ASHRAE Std 62.1 - Ventilation for Acceptable Indoor Air Quality.
- D. ASHRAE Std 90.1 I-P - Energy Standard for Buildings Except Low-Rise Residential Buildings.
- E. ASHRAE Std 135 - A Data Communication Protocol for Building Automation and Control Networks.
- F. NFPA 70 - National Electrical Code.
- G. NFPA 90A - Standard for the Installation of Air-Conditioning and Ventilating Systems.
- H. UL (DIR) - Online Certifications Directory.

#### **1.02 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data:
  - 1. Published Literature: Indicate dimensions, weights, capacities, ratings, gauges and finishes of materials, and electrical characteristics and connection requirements.
  - 2. Filters: Data for filter media, filter performance data, filter assembly, and filter frames.
  - 3. Fans: Performance and fan curves with specified operating point clearly plotted, power, RPM.
  - 4. Sound Power Level Data: Fan outlet and casing radiation at rated capacity.
  - 5. Electrical Requirements: Power supply wiring including wiring diagrams for interlock and control wiring, clearly indicating factory-installed and field-installed wiring.
- C. Shop Drawings: Indicate assembly, unit dimensions, weight loading, required clearances, construction details, field connection details, and electrical characteristics and connection requirements.
- D. Executed Warranty: Submit documentation of final executed warranty completed in Owner's name and registered with manufacturer.
- E. Manufacturer's Instructions: Include installation instructions.
- F. Maintenance Data: Include instructions for lubrication, filter replacement, motor and drive replacement, spare parts lists, and wiring diagrams.
- G. Maintenance Materials: Furnish the following for Owner's use in maintenance of project.
  - 1. See Section 01 60 00 - Product Requirements for additional provisions.
  - 2. Extra Filters: One set for each unit.

### **1.03 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacturing the type of products specified in this section, with minimum three years of documented experience.

### **1.04 DELIVERY, STORAGE, AND HANDLING**

- A. Accept products on site in factory-fabricated protective containers, with factory-installed shipping skids and lifting lugs. Inspect for damage.
- B. Store in clean dry place and protect from weather and construction traffic. Handle carefully to avoid damage to components, enclosures, and finish.
- C. Do not operate units until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.

### **1.05 WARRANTY**

- A. See Section 01 78 00 - Closeout Submittals for additional warranty requirements.
- B. Provide minimum one year manufacturer warranty covering repair or replacement due to defective materials or workmanship.

## **PART 2 PRODUCTS**

### **2.01 MANUFACTURERS**

- A. Daikin Applied
- B. Aeon
- C. Trane Technologies
- D. PACE a brand of Johnson Controls International, PLC[<>]
- E. York, a brand of Johnson Controls International, PLC: [www.york.com/#sle](http://www.york.com/#sle).
- F. Substitutions: See Section 01 60 00 - Product Requirements.

### **2.02 REGULATORY REQUIREMENTS**

- A. Products Requiring Electrical Connection: Listed and classified by UL (DIR) as suitable for the purpose specified and indicated.

### **2.03 CONSTRUCTION**

- A. Furnish sectionalized weatherproof double wall casing, including unit floor, of insulated steel suitable for roof curb mounting with bonderized paint finish and all necessary access panels to service fan bearings, coils and dampers. Complete with insulated waterproofed drain pan. Furnish blank section as indicated.
- B. Furnish insulated pipe enclosures with roof curb bump-outs and hinged access doors to allow piping to rise up through the roof within the unit curb base. Pipe enclosures shall be the largest size available to maximum internal space for piping insulation, valves, and thermometers, and to facilitate future service and/or valve replacements.
- C. Variable aspect ratio as required to meet dimensional requirements as scheduled.

- D. Provide coils with a maximum fin spacing of 14 fins per inch.
- E. Drainable hot water coil constructed of copper tubes, aluminum fins and 3-way valve (where specified on plans).
- F. Standard single serpentine drainable chilled water coil constructed of copper tubes and aluminum fins as indicated.
- G. Furnish flat arrangement 1" thick low velocity throwaway MERV 8 pre-filters.
- H. Furnish an angle or flat arrangement with 2" thick low velocity throwaway MERV 13 final filters.
- I. Furnish mixing box as indicated with interconnected brass pivoted, opposed blade, fresh air and return air dampers. Damper blades arranged to direct air stream at each other.
- J. Furnish filter draft gauge with 0" to 2" H<sub>2</sub>O range scale.
- K. Disconnect shall be pre-wired.
- L. Convenience outlet (powered by Electrical Contractor).

#### **2.04 FAN SECTION**

- A. Plenum airfoil centrifugal wheel with ball bearing supports, grease bearing extensions, NEMA approved resiliently mounted open ball bearing motor with adjustable motor mount, direct drive and vibration isolation.
- B. Fan diameter and speed as required such that the setpoint of the variable frequency drive does not exceed 65 Hz to meet the scheduled design parameters.

#### **2.05 COIL SECTION**

- A. Casing: Provide access to both sides of coils. Enclose coils with headers and return bends fully contained within casing. Slide coils into casing through removable end panel with blank off sheets and sealing collars at connection penetrations.
- B. Drain Pans: 24 inch downstream of coil and down spouts for cooling coil banks more than one coil high.
- C. Eliminators: Three break of galvanized steel, mounted over drain pan.
- D. Air Coils:
  - 1. Certify capacities, pressure drops, and selection procedures in accordance with AHRI 410.
- E. Fabrication:
  - 1. Tubes: 5/8 inch OD seamless copper expanded into fins, brazed joints.
  - 2. Fins: Aluminum.
  - 3. Casing: Die formed channel frame of galvanized steel.
- F. Water Heating Coils:
  - 1. Headers: Cast iron, seamless copper tube, or prime coated steel pipe with brazed joints.
  - 2. Configuration: Drainable, with threaded plugs for drain and vent; serpentine type with return bends on smaller sizes and return headers on larger sizes.

G. Water Cooling Coils:

1. Headers: Cast iron, seamless copper tube, or prime coated steel pipe with brazed joints.
2. Configuration: Drainable, with threaded plugs for drain and vent; threaded plugs in return bends and in headers opposite each tube.

**2.06 FILTER AND AIR CLEANER SECTION**

- A. General: Provide filter sections with filter racks, minimum of one access door for filter removal, and filter block-offs to prevent air bypass.
- B. Differential Pressure Gauge:
1. Provide factory installed dial type differential pressure gauge, flush mounted with casing outer wall, and fully piped to both sides of each filter to indicate status.
  2. Maintain plus/minus 5 percent accuracy within operating limits of 20 degrees F to 120 degrees F.

**2.07 DAMPER SECTION**

- A. Mixing Section: Provide a functional section to support the damper assembly for modulating the volume of outdoor and return air.
- B. Damper Blades:
1. Double-skin airfoil design with metal, compressible jamb seals and extruded-vinyl blade-edge seals on each blade.
  2. Self-lubricating stainless steel or synthetic sleeve bearings.
  3. Comply with ASHRAE Std 90.1 I-P for rated maximum leakage rate.
  4. Provide leakage testing and pressure ratings in compliance with AMCA 500-D test methods.
  5. Arrange in parallel or opposed-blade configuration.

**2.08 ROOF MOUNTING CURB**

- A. Roof Mounting Curb: 14 inches high galvanized steel, 2"rigid fiberglass insulation, channel frame with gaskets and nailer strips.

**PART 3 EXECUTION**

**3.01 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Install unit on a supply/return air plenum curb.
- C. Furnish and install all equipment supports as indicated or required for the installation of units, including miscellaneous upper steel as required to frame into overhead construction for distribution of weight.

- D. Contractor shall check the plans and verify the proposed unit can be installed in the space allotted and still have adequate room for servicing. All piping and/or duct modifications required for installation of the unit shall be the responsibility of the Mechanical Contractor.
- E. Hot water coils shall be fitted with manual air vent assemblies at the top of each header and for each return bend header. Vent pipes shall extend through the exterior of the unit casing and each shall be complete with manual air vents.
- F. Hot water coils shall be fitted with drain piping at each header and for each return bend header. All drain pipes shall extend through the exterior of the unit casing and shall be fitted with full size drain valves with male hose bibb fitting.
- G. Install flexible duct connections between fan inlet and discharge ductwork and air handling unit sections. Ensure that metal bands of connectors are parallel with minimum 1 inch flex between ductwork and fan while running.
- H. Make connections to coils with unions or flanges.
- I. Hydronic Coils:
  - 1. Hydronic Coils: Connect water supply to leaving air side of coil (counterflow arrangement).
  - 2. Provide shut-off valve on supply line and lockshield balancing valve with memory stop on return line.
  - 3. Locate water supply at bottom of supply header and return water connection at top.
  - 4. Provide manual air vents at high points complete with stop valve.
  - 5. Ensure water coils are drainable and provide drain connection at low points.

### **3.02 SYSTEM STARTUP**

- A. Provide manufacturer's field representative to perform systems startup.

### **3.03 CLOSEOUT ACTIVITIES**

- A. See Section 01 78 00 - Closeout Submittals for closeout submittals.
- B. Demonstration: Demonstrate operation of system to Owner's personnel.
  - 1. Use operation and maintenance data as reference during demonstration.
  - 2. Briefly describe function, operation, and maintenance of each component.
- C. Training: Train Owner's personnel on operation and maintenance of system.
  - 1. Use operation and maintenance manual as training reference, supplemented with additional training materials as required.
  - 2. Provide minimum of two hours of training.
  - 3. Instructor: Manufacturer's training personnel.
  - 4. Location: At project site.

### **END OF SECTION**

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## **SECTION 23 74 16 - PACKAGED ROOFTOP AIR-CONDITIONING UNITS**

### **PART 1 GENERAL**

#### **1.01 RELATED REQUIREMENTS**

- A. Section 23 09 15 - DDC Points List
- B. Section 23 09 23 - Direct-Digital Control System for HVAC
- C. Section 23 09 54 - Electric Temperature Control Systems
- D. Section 23 09 93 - Sequence of Operations for HVAC Controls

#### **1.02 REFERENCE STANDARDS**

- A. AHRI 210/240 - Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment.
- B. AHRI 270 (SI/I-P) - Sound Performance Rating of Outdoor Unitary Equipment.
- C. NEMA EN 10250 - Enclosures for Electrical Equipment (1000 Volts Maximum).
- D. NFPA 90A - Standard for the Installation of Air-Conditioning and Ventilating Systems.

#### **1.03 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide capacity and dimensions of manufactured products and assemblies required for this project. Indicate electrical service with electrical characteristics and connection requirements, and duct connections.
- C. Shop Drawings: Indicate capacity and dimensions of manufactured products and assemblies required for this project. Indicate electrical service with electrical characteristics and connection requirements, and duct connections.
- D. Manufacturer's Instructions: Indicate assembly, support details, connection requirements, and include start-up instructions.
- E. Operation and Maintenance Data: Include manufacturer's descriptive literature, operating instructions, installation instructions, maintenance and repair data, and parts listing.
- F. Warranty: Submit manufacturer's warranty and ensure forms have been filled out in Owner's name and registered with manufacturer.
- G. Maintenance Materials: Furnish the following for Owner's use in maintenance of project.
  - 1. See Section 01 60 00 - Product Requirements for additional provisions.
  - 2. Extra Filters: One set for each unit.

#### **1.04 QUALITY ASSURANCE**

- A. Manufacturer Qualifications: Company specializing in manufacturing the type of products specified in this section, with minimum three years of documented experience.
- B. Products Requiring Electrical Connection: Listed and classified by Underwriters Laboratories Inc. as suitable for the purpose specified and indicated.

### **1.05 DELIVERY, STORAGE, AND HANDLING**

- A. Protect units from physical damage by storing off site until roof mounting curbs are in place and ready for immediate installation of units.

### **1.06 WARRANTY**

- A. See Section 01 78 00 - Closeout Submittals for additional warranty requirements.
- B. Provide a five year warranty to include coverage for refrigeration compressors.

## **PART 2 PRODUCTS**

### **2.01 PACKAGED ROOFTOP AIR-CONDITIONING UNITS**

- A. Manufacturers:
  - 1. Valent
  - 2. Trane
  - 3. Aeon
  - 4. Daikin Applied
  - 5. Greenheck
  - 6. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Description: Self-contained, packaged, factory assembled and prewired, consisting of steel cabinet with 2" thick insulated double-wall construction, all necessary access panels and fully weatherproof fan rooftop mounting. Unit to be completely factory prewired and shall include a control transformer and space for 3rd party controller, magnetic starter, weatherproof disconnect switch, convenience outlet (powered by Electrical Contractor) and a factory fabricated spring isolation insulated roof mounting curb.
  - 1. Outdoor air filter frames with 2" thick MERV 13 pleated throwaway filters.
  - 2. Outdoor air and return air dampers with modulating damper actuators for automatic operation.
  - 3. Exhaust air damper with 2-position actuator.
  - 4. Outdoor air measuring station.
  - 5. Compressor condensing section shall be complete with copper tube aluminum fin or aluminum microchannel condensing coils, direct drive propeller fans with ECM motors and vertical air discharge with fan guards. The unit shall have at least one modulating digital or variable speed scroll type compressor. Remaining compressors may be standard scroll type. Also furnish magnetic starters, automatic pumpdown control, time delay relays, current demand limiters, timed off cycle, high and low pressure cutouts, crankcase heaters, oil failure switch, full charge of compressor oil and refrigerant and a 5 year compressor warranty.

6. The cooling section shall have direct expansion type cooling coils constructed of copper tubes and aluminum fins, thermostatic expansion valves, liquid line solenoid valves as required and a watertight drain pan.
7. Hail guards for condenser coils.
8. Provide variable frequency drives for supply air and exhaust air fans.
9. Supply fan section shall include a plenum centrifugal fan with ball bearing supports, NEMA approved open ball bearing motor with adjustable motor mount, direct drive.
10. Exhaust air fan section shall include a plenum centrifugal fan with ball bearing supports, NEMA approved open ball bearing motor with adjustable motor mount, direct drive, opposed blade exhaust air dampers suitable for automatic operation.

## **2.02 OPERATING CONTROLS**

- A. Provide terminal strip on unit for connection of third-party operating controls. Terminal strip shall allow for enable/disable of heating and cooling stages and modulation of variable capacity compressor by 23 09 23 contractor.
- B. Provide units with outdoor air damper and return air damper. Furnish all dampers with 2-10VDC modulating actuators. Outdoor air damper shall have fail-closed actuators. Return air damper shall have fail-open actuator. Economizer control shall be decided by logic from 23 09 23 DDC.
- C. Provide unit with 2-position, fail-closed relief air damper.
- D. Provide integral clogged filter switch.
- E. Provide return air duct smoke detector.

## **PART 3 EXECUTION**

### **3.01 INSTALLATION**

- A. Install in accordance with manufacturer's instructions.
- B. Unit roof curb shall be installed per detail. Installation shall include minimum 6 inches of Rockwool insulation and two layers of 5/8" mold resistant gypsum board. All edges, seams, and joints shall be thoroughly sealed with acoustic sealant to eliminate noise penetration through any gaps around pipe risers or duct drops. Install galvanized steel channel all around the curb perimeter and duct drops for support of gypsum board as required. At contractor's option, roof curb may be installed with BRD Hushcore deck system, model HIC-DS-52.
- C. The Mechanical Contractor shall provide photo documentation of the roof curb sound control system installation to the Engineer for records and to verify compliance with the specifications and details, and also retain copies for his own records.
- D. Provide loop seal per detail at each cooling coil drain pan connection.

**3.02 SYSTEM STARTUP**

- A. Prepare and start equipment. Adjust for proper operation.

**END OF SECTION**

## **SECTION 23 81 26 - SMALL-CAPACITY SPLIT-SYSTEM AIR CONDITIONERS**

### **PART 1 GENERAL**

#### **1.01 SECTION INCLUDES**

- A. Air cooled condensing units.
- B. Indoor air handling (fan and coil) units for ducted systems.
- C. Controls.

#### **1.02 REFERENCE STANDARDS**

- A. AHRI 210/240 - Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment.
- B. AHRI 520 - Performance Rating of Positive Displacement Condensing Units.
- C. ASHRAE Std 15 - Safety Standard for Refrigeration Systems.
- D. ASHRAE Std 23 - Methods for Performance Testing Positive Displacement Refrigerant Compressors and Compressor Units.
- E. NEMA MG 00001 - Motors and Generators.
- F. UL 207 - Standard for Refrigerant-Containing Components and Accessories, Nonelectrical.

#### **1.03 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements, for submittal procedures.
- B. Product Data: Provide rated capacities, weights, accessories, electrical nameplate data, and wiring diagrams.
- C. Shop Drawings: Indicate assembly, required clearances, and location and size of field connections.
- D. Design Data: Indicate refrigerant pipe sizing.
- E. Warranty: Submit manufacturers warranty and ensure forms have been filled out in Owner's name and registered with manufacturer.
- F. Maintenance Materials: Furnish the following for Owner's use in maintenance of project.
  - 1. See Section 01 60 00 - Product Requirements, for additional provisions.

#### **1.04 QUALITY ASSURANCE**

#### **1.05 WARRANTY**

- A. See Section 01 78 00 - Closeout Submittals, for additional warranty requirements.

### **PART 2 PRODUCTS**

#### **2.01 MANUFACTURERS**

- A. Carrier Corporation: [www.carrier.com/#sle](http://www.carrier.com/#sle).
- B. Rheem Manufacturing Company Inc: [www.rheem.com/#sle](http://www.rheem.com/#sle).
- C. Trane Technologies, PLC: [www.trane.com/#sle](http://www.trane.com/#sle).

- D. York International Corporation / Johnson Controls: [www.york.com/#sle](http://www.york.com/#sle).
- E. Daikin.
- F. Substitutions: See Section 01 60 00 - Product Requirements.

## **2.02 SYSTEM DESIGN**

- A. Split-System Heating and Cooling Units: Self-contained, packaged, matched factory-engineered and assembled, pre-wired indoor and outdoor units; UL listed.
  - 1. Heating: Natural gas fired.
  - 2. Cooling: Outdoor electric condensing unit with evaporator coil in central ducted indoor unit.
  - 3. Provide refrigerant lines internal to units and between indoor and outdoor units, factory cleaned, dried, pressurized and sealed, with insulated suction line.
- B. Performance Requirements: See Drawings for additional requirements.

## **2.03 INDOOR AIR HANDLING UNITS FOR DUCTED SYSTEMS**

- A. Indoor Units: Self-contained, packaged, factory assembled, pre-wired unit consisting of cabinet, supply fan, heating and cooling element(s), controls, and accessories; wired for single power connection with control transformer.
  - 1. Air Flow Configuration: Horizontal.
  - 2. Cabinet: Steel with baked enamel finish, easily removed and secured access doors with safety interlock switches, glass fiber insulation with reflective liner.
- B. Supply Fan: Centrifugal type rubber mounted with direct or belt drive with adjustable variable pitch motor pulley.
  - 1. Motor: NEMA MG 1; 1750 rpm multiple speed, permanently lubricated, hinge mounted.
- C. Air Filters: 1 inch thick glass fiber, disposable type arranged for easy replacement.
- D. Evaporator Coils: Copper tube aluminum fin assembly, galvanized or polymer drain pan sloped in all directions to drain, drain connection, refrigerant piping connections, restricted distributor or thermostatic expansion valve.
  - 1. Construction and Ratings: In accordance with AHRI 210/240 and UL 207.
  - 2. Manufacturers: System manufacturer.

## **2.04 OUTDOOR UNITS**

- A. Outdoor Units: Self-contained, packaged, pre-wired unit consisting of cabinet, with compressor and condenser.
  - 1. Refrigerant: R-454B or R-32.
  - 2. Cabinet: Galvanized steel with baked enamel finish, easily removed and secured access doors with safety interlock switches, glass fiber insulation with reflective liner.
  - 3. Construction and Ratings: In accordance with AHRI 210/240 with testing in accordance with ASHRAE Std 23 and UL 207.

- B. Compressor: Hermetic, two speed 1800 and 3600 rpm, AHRI 520 resiliently mounted integral with condenser, with positive lubrication, crankcase heater, high-pressure control, motor overload protection, service valves and drier. Provide time delay control to prevent short cycling and rapid speed changes.
- C. Air Cooled Condenser: Aluminum fin and copper tube coil, AHRI 520 with direct drive axial propeller fan resiliently mounted, galvanized fan guard.
  - 1. Condenser Fans: Direct-drive propeller type.
- D. Accessories: Filter drier, high-pressure switch (manual reset), low pressure switch (automatic reset), service valves and gauge ports, thermometer well (in liquid line).
  - 1. Provide thermostatic expansion valves.
- E. Operating Controls:
  - 1. Control by room thermostat to maintain room temperature setting.

## **2.05 ACCESSORY EQUIPMENT**

- A. Room Thermostat: Wall-mounted, electric solid state microcomputer based room thermostat with remote sensor to maintain temperature setting; low-voltage; with following features:
  - 1. Automatic switching from heating to cooling.
  - 2. Thermostat Display:
    - a. Time of day.
    - b. Actual room temperature.
    - c. Programmed temperature.
    - d. Programmed time.
    - e. Duration of timed override.
    - f. System Mode Indication: Heating, Cooling, Fan Auto, Off, and On, Auto or On, Off.

## **PART 3 EXECUTION**

### **3.01 EXAMINATION**

- A. Verify that substrates are ready for installation of units and openings are as indicated on shop drawings.
- B. Verify that proper power supply is available and in correct location.
- C. Verify that proper fuel supply is available for connection.

### **3.02 INSTALLATION**

- A. Install in accordance with manufacturer's instructions and requirements of local authorities having jurisdiction.
- B. Install refrigeration systems in accordance with ASHRAE Std 15.

## **END OF SECTION**

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**SECTION 23 82 00 - CONVECTION HEATING AND COOLING UNITS**

**PART 1 GENERAL**

**1.01 SECTION INCLUDES**

- A. Hydronic finned tube radiation.
- B. Hydronic unit heaters.
- C. Fan-coil units.
- D. Blower-coil units.

**1.02 REFERENCE STANDARDS**

- A. AHRI 410 - Forced-Circulation Air-Cooling and Air-Heating Coils.
- B. AHRI 440 - Performance Rating of Room Fan-Coils.
- C. AHRI Directory of Certified Product Performance - Air-Conditioning, Heating, and Refrigeration Institute (AHRI).
- D. NFPA 70 - National Electrical Code.
- E. NFPA 90A - Standard for the Installation of Air-Conditioning and Ventilating Systems.

**1.03 ADMINISTRATIVE REQUIREMENTS**

**1.04 SUBMITTALS**

- A. See Section 01 30 00 - Administrative Requirements for submittal procedures.
- B. Product Data: Provide typical catalog of information including arrangements.
- C. Shop Drawings:

**PART 2 PRODUCTS**

**2.01 HYDRONIC FINNED TUBE RADIATION**

- A. Manufacturers:
  - 1. Sterling
  - 2. Rittling
  - 3. Vulcan
  - 4. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Heating elements to be constructed as indicated on schedule and of lengths as shown on plans. Lengths may not be varied unless approved by the Engineer in writing. Capacities may not be less than that indicated on the plans.
- C. Sloping top discharge with open bottom.
- D. Units to have end trim strips at all wall terminations and end caps at all other cabinet terminations.
- E. Furnish access panels for access to valves and traps consisting of 2 ft. long removable enclosure section.

- F. Finish: Factory applied baked enamel of color selected by Architect.

## **2.02 HYDRONIC UNIT HEATERS**

- A. Manufacturers:
1. Sterling
  2. Rittling
  3. Vulcan
  4. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Furnish units with direct driven propeller fan, hot water coil constructed of copper tubes and aluminum fins and totally enclosed resiliently mounted motor of speed indicated.
- C. Perform factory run test under normal operating conditions, water, and steam flow rates.
- D. Minimum 18 gauge, 0.0478 inch thick sheet steel casing with threaded pipe connections for hanger rods.
- E. Finish: Factory applied baked enamel.
- F. Air Outlet: Adjustable horizontal discharge louvers and safety fan guard.

## **2.03 FAN-COIL UNITS**

- A. Manufacturers:
1. Daikin
  2. Aeon
  3. Trane
  4. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Performance Data and Safety Requirements:
1. Unit capacities certified in accordance with AHRI 440.
  2. Provide products listed, classified, and labeled by Underwriters Laboratories Inc. (UL) as suitable for purpose indicated.
  3. Insulation to comply with NFPA 90A requirements for flame spread and smoke generation.
  4. Equipment wiring to comply with requirements of NFPA 70.
- C. Required Directory Listings: AHRI Directory of Certified Product Performance - Air-Conditioning, Heating, and Refrigeration Institute (AHRI).
- D. Horizontal Recessed Units:
1. Provide with a galvanized steel cabinet, easily removed panels, glass fiber insulation, with minimum 18 gauge, 0.0478 inch thick sheet steel bottom panel.
  2. Ducted Units: Provide with air inlet and outlet duct collars.
  3. Forward curved centrifugal fan with direct connected variable speed EC motor for control by BAS with built-in overload protection, access door flush mounted.
  4. Furnish with MERV 13 throwaway filters.

5. Furnish copper tube, aluminum fin four pipe two coil module as indicated. (Cooling coil shall be first in air stream).
6. Furnish insulated condensate drain pan on cooling units complete with prewired condensate overflow switch and fan interlock.
7. Cabinet to be baked enamel finish of manufacturers standard color as selected by Architect.

## **2.04 BLOWER-COIL UNITS**

- A. Manufacturers:
  1. Daikin
  2. Aeon
  3. Trane
  4. Substitutions: See Section 01 60 00 - Product Requirements.
- B. Performance Data and Safety Requirements:
  1. Coils rated and tested in accordance with AHRI 410.
  2. Provide products listed, classified, and labeled by Underwriters Laboratories Inc. (UL) as suitable for purpose indicated.
  3. Comply with NFPA 90A for unit construction, including filters and related equipment, for protection of life and property from fire, smoke, and gases resulting from conditions having manifestations similar to fire.
- C. Construction:
  1. Furnish unit with forward curved centrifugal fan with variable speed EC motor for control by BAS with built-in overload protection and access door.
  2. Furnish with two-inch thick, MERV 13 throwaway filters.
  3. Furnish copper tube, aluminum fin four pipe two coil module as indicated. (Cooling coil shall be first in air stream).
  4. Furnish insulated condensate drain pan complete with prewired condensate overflow switch and fan interlock.
  5. Cabinet to be 18 gauge insulated steel casing with baked enamel finish.

## **PART 3 EXECUTION**

### **3.01 EXAMINATION**

- A. Verify that surfaces are suitable for installation.
- B. Verify that field measurements are as indicated on drawings.

### **3.02 PREPARATION**

### **3.03 INSTALLATION**

- A. Install in accordance with manufacturer's recommendations.

- B. Install equipment exposed to finished areas after walls and ceilings are finished and painted.
- C. Do not damage equipment or finishes.
- D. Finned Tube Radiation:
  - 1. Locate on outside walls and run cover continuously wall-to-wall unless otherwise indicated.
  - 2. Center elements under window with elements of equal length centered under each window for multiple windows.
  - 3. Install wall angles and end caps where units butt against walls.
  - 4. Align cabinet joints with window mullions.
  - 5. Install wall angles where units butt against walls and align cabinet joints with window mullions.
- E. Unit Heaters:
  - 1. Hang from building structure, with pipe hangers anchored to building, not from piping or electrical conduit.
  - 2. Mount as high as possible to maintain greatest headroom unless otherwise indicated.
- F. Fan-Coil Units:
  - 1. Install as indicated.
  - 2. Coordinate to ensure correct recess size for recessed units.
- G. Units with Hydronic Coils:
  - 1. Provide with shut-off valve on supply piping and tamper-proof, balancing valve with memory stop on return piping.
- H. Units with Cooling Coils:
  - 1. Connect drain pan to condensate drain.
- I. Blower-Coil Units:
  - 1. Verify all surfaces and openings at unit location can suitably accommodate unit(s).
  - 2. Install in accordance with manufacturer's recommendations.
  - 3. Provide manual shut-off valve on hydronic supply side of coil and balancing valve with memory stop on return side.

### **3.04 CLEANING**

- A. After construction and painting is completed, clean exposed surfaces of units.
- B. Vacuum clean coils and inside of units.
- C. Touch-up marred or scratched surfaces of factory-finished cabinets using finish materials furnished by the manufacturer.
- D. Install new filters.

### **3.05 CLOSEOUT ACTIVITIES**

- A. See Section 01 78 00 - Closeout Submittals for closeout submittals.

- B. See Section 01 79 00 - Demonstration and Training for additional requirements.

**3.06 PROTECTION**

- A. Provide finished cabinet units with protective covers during the balance of construction.

**END OF SECTION**