100% Construction Documents

Leon County Annex
Bank of America
7th Floor HVAC Remodel

H2Engineering Project No: 11-55

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Division	Section Title

SPECIFICATIONS GROUP

Facility Services Subgroup

DIVISION 23 - HEATING VENTILATING AND AIR CONDITIONING

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SECTION 230100 – GENERAL PROVISIONS FOR HVAC

PART 1 - GENERAL

1.1 GENERAL REQUIREMENTS

A. General Conditions, Supplementary Conditions, applicable provisions of Division 01, General Requirements, and other provisions and requirements of the contract documents apply to work of Division 23, Heating Ventilating and Air Conditioning.

B. Applicable provisions of this section apply to all sections of Division 23, Heating, Ventilating and Air Conditioning.

C. All Division 23 sections shall be considered to be integrated with each other.

D. Investigate all alternates, addenda and allowances as they relate to work of Division 23.

E. Approval of the subcontractors will be based on experience, qualifications and financial responsibility.

1.2 QUALITY ASSURANCE

A. General:

1. It is the intent of the drawings and specifications to obtain a complete, operable and satisfactory installation.
2. All materials shall be new, be properly labeled and/or identified and be in full compliance with the contract documents.
3. All work shall comply with applicable Codes and Standards.
4. Manufacturer's model names and numbers used in this Division of the specifications are subject to change per manufacturer's action. Contractor shall therefore verify them with manufacturer's representative before ordering any product or equipment.

B. Manufacturers: Firms regularly engaged in manufacture of general use equipment with characteristics, pipe sizes and capacities required, whose products have been in satisfactory use in similar service for not less than 5 years.

C. Installer: A firm with at least 3 years of successful installation experience on projects with installation work similar to that required for the project.

D. UL and NEMA Compliance: Provide electric motors and products which have been listed and labeled by Underwriters Laboratories and comply with NEMA standards.

E. Certification, Equipment Performance: Provide equipment whose performances, under specified operating conditions, are certified by manufacturer.

1.3 CODE REQUIREMENTS

A. Perform work in accordance with applicable statutes, ordinances, codes, and regulations of governmental authorities having jurisdiction. Applicable codes include the following:

1. ASHRAE

Standard 55 Thermal Environmental Conditions for Human Occupancy
Standard 62 Ventilation Standard for Acceptable Indoor air Quality
Standard 90.1 Energy Standard for Buildings Except Low Rise Residential Buildings]

2. ASME Boiler and Pressure Vessel Code 2004 Edition w/ 2005 & 2006 Addenda
Section VIII Rules for Construction of Pressure Vessels
3. Occupational Safety and Health Regulations (OSHA).
4. National Fire Codes

NFPA 1 Uniform Fire Code
NFPA 70 National Electrical Code
NFPA 90A Standard for the Installation of Air Conditioning and Ventilation Systems
NFPA 90B Standard for the Installation of Warm Air Heating and Air Conditioning Systems
NFPA 91 Standard for the Installation of Blower and Exhaust Systems

NFPA 101 Life Safety Code
5. Florida Building Codes 2010 Edition
Building Code - Chapter 11 Florida Accessibility Code
Building Code - Chapter 13 Energy Efficiency Code
Mechanical Code
6. Florida Administrative Code

Chapter 9B-7 Florida Building Commission Handicapped Accessibility Standards
Chapter 61G15-34 Responsibility Rules of Professional Engineers Concerning the Design of Mechanical Systems
Chapter 69A-60 The Florida Fire Prevention Code
7. ADA Accessibility Guidelines for Buildings (ADAAG)

B. Resolve, in writing, any code violation discovered in contract documents with the Engineer prior to bidding. After award of the contract, make any correction or addition necessary for compliance with applicable codes at no additional cost to Owner.

C. Conflicts: Where there is a conflict between the contract document and an applicable "CODE", the "CODE" shall govern except where the requirements of the contract documents are more stringent; where there is a conflict between the contract drawings and the contract specifications, the most stringent shall govern.

D. The installer shall include in the work, without extra cost to the Owner, any labor, materials, services, apparatus and drawings required to comply with all applicable laws, ordinances, rules and regulations.

1.4 PERMITS FEES AND INSPECTIONS

A. Obtain and pay for all permits, fees, and inspections.

B. Deliver all certificates of inspection issued by authorities having jurisdiction to the Engineer.

1.5 REFERENCE SPECIFICATIONS AND STANDARDS

A. Materials which are specified by reference to Federal Specifications; ASTM, ASME, ANSI, or AWWA Specifications; Federal Standards; or other standard specifications must comply with latest editions, revisions, amendments or supplements in effect on date bids are received. Specifications and standards are minimum requirements for all equipment, material and work. In instances where capacities, size or other feature of equipment, devices or materials exceed these minimums, meet listed or shown capacities.

B. Whenever a reference is made to a standard, installation and materials shall comply with the latest published edition of the standard at the time project is bid unless otherwise specified herein.

1.6 CONTRACT DOCUMENTS

A. Examine all drawings and specifications carefully before submitting a bid. Architectural drawings take precedence over mechanical or electrical drawings with reference to building construction. If discrepancies or conflicts occur between drawings, or between drawings and specifications, notify the Engineer in writing prior to bid date; however, the most stringent requirement shall govern.

B. For purposes of clearness and legibility, drawings are essentially diagrammatic and, although size and location of equipment are drawn to scale wherever possible, Contractor shall make use of all data in all of the contract documents and shall verify this information at the building site.

C. The drawings indicate required size and points of termination of pipes, conduits and ducts and suggest proper routes to conform to structure avoid obstructions and preserve clearances. However, it is not intended that drawings indicate all necessary offsets, and it shall be the responsibility of the Contractor to make the installation in such a manner as to conform to structure, avoid obstructions, preserve headroom and keep openings and passageways clear, without further instructions or cost to the Owner.

D. Furnish, install and/or connect with appropriate services all items shown on any drawing without additional compensation.

E. Consider the terms "provide" and "install" as synonymous with "furnish and install".

F. Any and all questions about a subcontractor's scope of work responsibility shall be addressed to and answered by the Owner.

G. Questions About Construction Documents: Any and all questions shall be submitted through the proper channels IN WRITING and, in turn, shall be answered by the Engineer in writing. All telephone conversations shall be considered unofficial and, as such, shall not be considered official or binding responses to Contractor's questions.

1.7 MATERIALS AND EQUIPMENT

A. Furnish new and unused materials and equipment manufactured in the U.S.A. Where two or more units of the same type or class of equipment are required provide units of a single manufacturer.

B. Only manufacturer's products specified hereinafter or listed in an addendum, prior to the acceptance of bids, shall be furnished and installed under this contract.

C. All products used in this project installation shall be new and currently under manufacture and shall have been applied in similar installations for a minimum of two years. This installation shall not be used as a test site for any new products unless explicitly approved by the Owner in writing. Spare parts shall be available for at least five years after completion of this contract.

1.8 SUBSTITUTIONS

A. All substitutes or alternate manufacturers' products must meet detailed specifications, size and arrangement of equipment specified. Equipment must fit allocated space. Only products equal to that specified will be considered.

B. If the approved equal substitution contains differences or omissions not specifically called to the

attention of the Engineer, those features shall be added to the substituted product at the Contractor's expense.

1.9 ADDITIONAL WORK

A. Design is based on equipment as described in the drawings and specifications. Any required changes in foundation bases, electrical requirements, wiring, conduit, connections, piping, controls, openings, etc., shall be paid for by this Contractor.

1.10 GUARANTEE

A. Guarantee work and equipment for one year from the date of final acceptance of the project, and during that period make good any faults or imperfections that may arise due to defects or omissions in materials or workmanship. Furnish a copy of the manufacturer's guarantee and/or warranty for each piece of equipment.

B. Furnish a letter from the control manufacturer stating that all controls have been checked for operation and calibration, and the system is operating as designed.

C.

PART 2 - PRODUCTS

PART 3 - EXECUTION

3.1 WORKMANSHIP

A. Install materials and equipment in a professional manner. The Engineer may direct replacement of items which, in his opinion, do not present a professional appearance. Replace or reinstall items at the expense of the Contractor.

3.2 SUPERVISION OF WORK

A. Perform all work under the direct supervision of an experienced, qualified superintendent.

3.3 CONNECTING TO WORK OF OTHERS

A. Examine all work installed by others where it applies to work of Division 23. Notify the Engineer if conditions exist which prevent satisfactory results. Start of work by the Contractor shall be construed as acceptance by him of all claims or questions as to suitability of the work of others to receive his work.

3.4 DAMAGE TO OTHER WORK AND PERSONNEL

A. Adequately protect work, equipment, fixtures, and materials. At work completion, all work must be clean and in good condition.

B. Carry insurance as prescribed by law and as required in this specification for protection of employees, other persons, materials and equipment on the building site.

C. Contractor shall pay for all damages caused by his personnel, including his subcontractors.

3.5 OBSTRUCTIONS

A. The drawings indicate certain information pertaining to obstructions which has been taken from available drawings. Such information is not guaranteed, however, as to accuracy of location or complete information.

B. Before any cutting operations are begun, verify with Owner's representative, and other interested parties that all available information has been provided. Verify locations given.

C. Should obstruction be encountered, whether shown or not, alter routing of new work, reroute existing lines, remove obstruction where permitted, or otherwise perform whatever work is necessary to satisfy the purpose of the new work and leave existing services and structures in a satisfactory and serviceable condition.

D. Assume total responsibility for and repair any damage to existing utilities or construction, whether or not such existing facilities are shown.

3.6 SPACE REQUIREMENTS

A. Consider space limitations imposed by contiguous work in selection and location of equipment and material. Do not provide equipment or material which is not suitable in this respect.

3.7 CUTTING AND PATCHING

A. Cut and patch all walls, partitions, floors, pits and chases in wood and masonry as indicated or required by the contract documents or as directed by the Engineer.

B. Obtain approval of Engineer prior to cutting of steel, wood or other structural member.

C.

D. Openings through concrete structures shall be "core bored"; where 3 or more openings penetrate in the same location the concrete may be sawed. All penetrations shall be re-sealed around pipes with "WATER-PLUG" by Thoro with top surface finished smooth.

3.8 REMOVAL OF RUBBISH

A. During construction keep the job site clean and remove all rubbish.

B. Upon completion of work leave the premises and work in a clean and acceptable condition. Remove all tools, scaffolding, materials and rubbish from the building and site. Clean all pipe chases. Remove all plaster, concrete, cement, etc. from exposed and concealed pipe, hangers and equipment prior to painting and/or concealment.

3.9 "FIRE AND SMOKE RATED" WALLS, FLOORS, ROOFS AND CEILINGS

A. Where "rated" walls, floor, roofs and ceilings are penetrated or cut to install equipment, materials, devices, etc. the Contractor shall provide and install all materials required to re-establish the rating of the wall, floor, roof or ceiling to the satisfaction of the authority having jurisdiction.

3.10 LUBRICATION AND OIL

A. Provide a complete charge of correct lubricant for each item of equipment requiring lubrication.

3.11 PRODUCT DELIVERY, STORAGE AND HANDLING:

A. Deliver and store equipment and products in factory wrapped packages which properly protect equipment against weather, dirt and damage. Materials shall not be stored in contact with ground or floor.

B. Handle equipment carefully to avoid damage to motors, components, enclosures and finish. Do not install damaged units; replace and return damaged units to manufacturer.

3.12 NOISE AND VIBRATION

A. Select equipment to operate with minimum noise and vibration. If objectionable noise or vibration is produced or transmitted to or through the building structure by equipment, piping, ducts or other parts of work, rectify such conditions without cost to the Owner.

3.13 TESTS

A. Include all tests specified and/or required under laws, rules and regulations of all departments having jurisdiction. Tests shall also be performed as indicated herein and other sections of the specifications.

B. After all mechanical systems have been completed and put into operation, subject each system to an operating test under design conditions to insure proper sequence and operation throughout the range of operation. Make adjustments as required to insure proper functioning of all systems.

C. All parts of the work and associated equipment shall be tested and adjusted to work properly and be left in perfect operating condition.

D. Correct defects disclosed by these tests without any additional cost to the Owner. Repeat tests on repaired or replaced work.

E. Maintain a log of all tests being conducted and have it available for review by the Engineer. Log to indicate date, type of tests, duration, and defects noted and when corrected.

F. Special tests on individual systems are specified under individual sections.

G. Mechanical Contractor shall provide personnel, tools and equipment and assist the Test and Balance Contractor in making any adjustments necessary to meet the test and balance requirements.

3.14 OPERATING AND MAINTENANCE INSTRUCTIONS

A. Secure three copies of operating and maintenance instructions, service manuals, and parts lists applicable to each item of equipment furnished. Deliver three bound sets for the Owner's use. Include nameplate data and design parameters in operation and maintenance manuals. Clearly distinguish between information which applies to the equipment and information which does not apply. Delivery of required documents is a condition of final acceptance.

B. Provide detailed, step-by-step written instructions to direct the operator in operating procedures for initial start-up, normal shutdown, extended shutdown and extreme ambient temperature condition. Provide four copies of these instructions with laminated plastic protective cover.

3.15 PROJECT RECORD DOCUMENTS

A. Preparation: Maintain at the job site a separate set of white prints of the contract drawings for the sole purpose of recording the "as-built" changes and diagrams of those portions of work in which actual construction is significantly at variance with the contract drawings. Mark the drawings with a No. B or softer pencil. Prepare, as the work progresses and upon completion of work, drawings clearly indicating locations of various piping, valves, ductwork, traps, equipment, and other pertinent items, as installed.

B. Deliver: At conclusion of project, provide without cost to Owner as-built reproducibles of original mechanical drawings. Delivery of as-built reproducibles is a condition of final acceptance. In addition to final as-built drawings, each month during construction deliver current marked–up prints to the Engineer.

3.16 TRAINING

A. Upon completion of work, and at time designated by the Owner's representative, provide services of competent representatives of the Contractor to instruct Owner's representative in the operation and maintenance of the entire system.

B. Training sessions shall be videotaped and tapes given to the Owner.

3.17 SERVICE

A. Perform service work during the guarantee period to include the following: adjustment or replacement of all defective materials and equipment furnished; ; cleaning of strainers.

1. Cleaning of air filters is limited to 30 days after final acceptance of the project.
2. Perform service quarterly and provide the Owner with a written report.

3.18 AIR CONDITIONING SYSTEM OPERATION

A. Contractor shall strictly adhere to the following procedures when HVAC equipment is used by the Contractor during construction:

1. Contractor shall notify the Owner in writing of his intent to use the equipment to dehumidify the building and control air borne contaminants.
2. For each piece of equipment a record log shall be maintained which indicates starting date and every day of operation. Log shall indicate all service and maintenance work done on the equipment.
3. Filters shall be in place and replaced as recommended by the manufacturer. Record of filter change to be maintained at each filter location and air moving equipment. Filters shall be extended surface pleated type as specified in Section 234100.
4. In the case of high dust loads caused by brooming, sanding, etc.:

    a. Acoustical ceilings in return air plenums shall not be installed.
    b. Filters shall be located to protect all ductwork and equipment.

5. Upon completion of the work, and prior to substantial completion inspection, the interior of units shall be vacuum cleaned, coils and drain pans washed.
6. All costs for filtration, cleaning, testing, re-cleaning and re-testing shall be borne by the Contractor.

3.19 INSTRUCTIONS

A. Included within the scope of Division 23 is work where equipment and/or materials are furnished or required by this Division and installed under another Division (designated by the Contractor). It is the responsibility of the Contractor to see that all such work is included in the contract bid amount and completed during construction.

B. Each Contractor shall visit the building and fully familiarize himself with existing conditions and account for these conditions in the submitted bids.

C. Schedule interruptions in utility services well in advance to suit the Owner's convenience and obtain approval from the Engineer. Utility interruptions may require overtime work on the part of the Contractor. Include this overtime work as a requirement of Division 15. No additional compensation will be allowed for such overtime work.

D. The Contractor shall coordinate the work and the work schedule on a weekly basis with the Owner.

E. All wiring, electrical equipment (motor starters, disconnects, conduit, switches, etc.) required in Division 23 shall be furnished and installed under Division 26, except where otherwise noted.

F. All motors 15 HP and above shall have reduced voltage type starters.

END OF SECTION 230100

SECTION 230513 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

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

1.3 COORDINATION

A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:

1. Motor controllers.
2. Torque, speed, and horsepower requirements of the load.
3. Ratings and characteristics of supply circuit and required control sequence.
4. Ambient and environmental conditions of installation location.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

A. Comply with requirements in this Section except when stricter requirements are specified in HVAC equipment schedules or Sections.

B. Comply with NEMA MG 1 unless otherwise indicated.

C. Comply with IEEE 841 for severe-duty motors.

2.2 MOTOR CHARACTERISTICS

A. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet (1000 m) above sea level.

B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

2.3 POLYPHASE MOTORS

A. Description: NEMA MG 1, Design B, medium induction motor.

B. Efficiency: Energy efficient, as defined in NEMA MG 1.

C. Service Factor: 1.15.

D. Multispeed Motors: Variable torque.

1. For motors with 2:1 speed ratio, consequent pole, single winding.
2. For motors with other than 2:1 speed ratio, separate winding for each speed.

E. Multispeed Motors: Separate winding for each speed.

F. Rotor: Random-wound, squirrel cage.

G. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.

H. Temperature Rise: Match insulation rating.

I. Insulation: Class F .

J. Code Letter Designation:

1. Motors 15 HP and Larger: NEMA starting Code F or Code G.
2. Motors Smaller than 15 HP: Manufacturer's standard starting characteristic.

K. Enclosure Material: Cast iron for motor frame sizes 324T and larger; rolled steel for motor frame sizes smaller than 324T .

2.4 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

A. Motors Used with Reduced-Voltage and Multispeed Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals in motor terminal box, suited to control method.

B. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.

1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.
2. Energy- and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.

4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

C. Severe-Duty Motors: Comply with IEEE 841, with 1.15 minimum service factor.

2.5 SINGLE-PHASE MOTORS

A. Motors larger than 1/20 hp shall be one of the following, to suit starting torque and requirements of specific motor application:

1. Permanent-split capacitor.

B. Multispeed Motors: Variable-torque, permanent-split-capacitor type.

C. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.

D. Motors 1/20 HP and Smaller: Shaded-pole type.

E. Thermal Protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 230513

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SECTION 230516 - EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Rubber packless expansion joints.

1.3 PERFORMANCE REQUIREMENTS

A. Compatibility: Products shall be suitable for piping service fluids, materials, working pressures, and temperatures.

B. Capability: Products to absorb 200 percent of maximum axial movement between anchors.

1.4 ACTION SUBMITTALS

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

1.5 INFORMATIONAL SUBMITTALS

A. Welding certificates.

B. Product Certificates: For each type of expansion joint, from manufacturer.

1.6 CLOSEOUT SUBMITTALS

A. Maintenance Data: For expansion joints to include in maintenance manuals.

1.7 QUALITY ASSURANCE

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

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."

PART 2 - PRODUCTS

2.1 PACKLESS EXPANSION JOINTS

A. Rubber, Expansion-Compensator Packless Expansion Joints:

1. Basis-of-Design Product: Subject to compliance with requirements, provide Twin City Hose, Inc.; MSU or comparable product by one of the following:

    a. Metraflex, Inc.; TSUC
    b. Mason Industries, Inc.; Mercer Rubber Co.

2. Material: Twin reinforced-rubber spheres with external restraining cables.
3. Minimum Pressure Rating: 150 psig at 170 deg F (1035 kPa at 77 deg C) unless otherwise indicated.
4. End Connections for NPS 2 (DN 50) and Smaller: Threaded.

B. Rubber Packless Expansion Joints:

1. Basis-of-Design Product: Subject to compliance with requirements, provide Twin City Hose, Inc.; MST or comparable product by one of the following:

    a. Mason Industries, Inc.; Mercer Rubber Co.
    b. Metraflex, Inc.; TSUC or DSRC series

2. Standards: ASTM F 1123 and FSA's "Technical Handbook: Non-Metallic Expansion Joints and Flexible Pipe Connectors."
3. Material: Fabric-reinforced rubber complying with FSA-NMEJ-703.
4. Spherical Type: Multiple spheres.
5. Minimum Pressure Rating for NPS 1-1/2 to NPS 4 (DN 40 to DN 100): 150 psig (1035 kPa) at 220 deg F (104 deg C) .
6. Material for Water: EPDM .
7. End Connections: Full-faced, integral steel flanges with steel retaining rings.

PART 3 - EXECUTION

3.1 EXPANSION-JOINT INSTALLATION

A. Install expansion joints of sizes matching sizes of piping in which they are installed.

B. Install rubber packless expansion joints according to FSA-NMEJ-702.

3.2 PIPE LOOP AND SWING CONNECTION INSTALLATION

A. Connect risers and branch connections to mains with at least five pipe fittings including tee in main.

B. Connect risers and branch connections to terminal units with at least four pipe fittings including tee in riser.

C. Connect mains and branch connections to terminal units with at least four pipe fittings including tee in main.

END OF SECTION 230516

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SECTION 230517 - SLEEVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Sleeves.
2. Grout.

1.3 ACTION SUBMITTALS

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

PART 2 - PRODUCTS

2.1 SLEEVES

A. Galvanized-Steel-Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, zinc coated, with plain ends.

2.2 GROUT

A. Standard: ASTM C 1107/C 1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.

B. Characteristics: Nonshrink; recommended for interior and exterior applications.

C. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.

D. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 SLEEVE INSTALLATION

A. Install sleeves for piping passing through penetrations in floors, partitions, roofs, and walls.

B. For sleeves that will have sleeve-seal system installed, select sleeves of size large enough to provide 1-inch (25-mm) annular clear space between piping and concrete slabs and walls.

1. Sleeves are not required for core-drilled holes.

C. Install sleeves in concrete floors, concrete roof slabs, and concrete walls as new slabs and walls are constructed.
1. Cut sleeves to length for mounting flush with both surfaces.

a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 2 inches (50 mm) above finished floor level.

2. Using grout, seal the space outside of sleeves in slabs and walls without sleeve-seal system.

D. Install sleeves for pipes passing through interior partitions.

1. Cut sleeves to length for mounting flush with both surfaces.
2. Seal annular space between sleeve and piping or piping insulation; use joint sealants appropriate for size, depth, and location of joint. Comply with requirements for sealants specified in Division 07 Section "Joint Sealants."

E. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements for firestopping specified in Division 07 Section "Penetration Firestopping."

3.2 SLEEVE SCHEDULE

A. Use sleeves for the following piping-penetration applications:

1. Concrete Slabs above Grade: Galvanized Steel Pipe Sleeves
2. Interior Partitions: Galvanized Steel Pipe Sleeves

END OF SECTION 230517

SECTION 230518 - ESCUTCHEONS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Escutcheons.

1.3 ACTION SUBMITTALS

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

PART 2 - PRODUCTS

2.1 ESCUTCHEONS

A. One-Piece, Cast-Brass Type: With polished, chrome-plated and rough-brass finish and setscrew fastener.

B. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with chrome-plated finish and spring-clip fasteners.

C. One-Piece, Stamped-Steel Type: With chrome-plated finish and spring-clip fasteners.

D. Split-Casting Brass Type: With polished, chrome-plated and rough-brass finish and with concealed hinge and setscrew.

E. Split-Plate, Stamped-Steel Type: With chrome-plated finish, concealed hinge, and spring-clip fasteners.

2.2 FLOOR PLATES

A. One-Piece Floor Plates: Cast-iron flange.

B. Split-Casting Floor Plates: Cast brass with concealed hinge.

PART 3 - EXECUTION

3.1 INSTALLATION

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

B. Install escutcheons with ID to closely fit around pipe, tube, and insulation of piping and with OD that completely covers opening.

1. Escutcheons for New Piping:

a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
b. Insulated Piping: One-piece, stamped-steel type .
c. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass type with polished, chrome-plated finish.
d. Bare Piping at Ceiling Penetrations in Finished Spaces: One-piece, cast-brass type with polished, chrome-plated finish.
e. Bare Piping in Unfinished Service Spaces: One-piece, cast-brass type with rough-brass finish.
f. Bare Piping in Equipment Rooms: One-piece, cast-brass type with rough-brass finish.

2. Escutcheons for Existing Piping:

a. Insulated Piping: Split-plate, stamped-steel type with concealed hinge.
b. Bare Piping at Wall and Floor Penetrations in Finished Spaces: Split-casting brass type with polished, chrome-plated finish.
c. Bare Piping at Ceiling Penetrations in Finished Spaces: Split-casting brass type with polished, chrome-plated finish.
d. Bare Piping in Unfinished Service Spaces: Split-casting brass type with rough-brass finish.
e. Bare Piping in Equipment Rooms: Split-casting brass type with rough-brass finish.

C. Install floor plates for piping penetrations of equipment-room floors.

D. Install floor plates with ID to closely fit around pipe, tube, and insulation of piping and with OD that completely covers opening.
1. Existing Piping: Split-casting, floor-plate type.

3.2 FIELD QUALITY CONTROL

A. Replace broken and damaged escutcheons and floor plates using new materials.

END OF SECTION 230518

SECTION 230519 - METERS AND GAGES FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Liquid-in-glass thermometers.
2. Thermowells.
3. Test plugs.
4. Test-plug kits.
5. Venturi flowmeters.

1.3 ACTION SUBMITTALS

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

1.4 INFORMATIONAL SUBMITTALS

A. Product Certificates: For each type of meter and gage, from manufacturer.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For meters and gages to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 LIQUID-IN-GLASS THERMOMETERS

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

1. Basis-of-Design Product: Subject to compliance with requirements, provide Trerice, H.O. Co.; BX9 or comparable product by one of the following:

a. Miljoco Corporation.
b. Weiss Instruments, Inc.

c. Winters Instruments - U.S.

2. Standard: ASME B40.200.
3. Case: Cast aluminum 9-inch (229-mm) nominal size unless otherwise indicated; provide weatherproofed case for outdoor installations.
4. Case Form: Adjustable angle unless otherwise indicated.
5. Tube: Glass with magnifying lens and blue organic liquid.
6. Tube Background: Nonreflective aluminum with permanently etched scale markings graduated in deg F (deg C) .
7. Window: Indoors: Glass; Outdoors: UV Protective Plastic.
8. Stem: Brass of length to suit installation.

   a. Design for Air-Duct Installation: Provide aluminum ventilated air-duct stem with 3-inch O.D. reversible aluminum flange and perforated aluminum guard.
   b. Design for Thermowell Installation: Bare stem.

9. Connector: 1-1/4 inches (32 mm), with ASME B1.1 screw threads.
10. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

2.2 DUCT-THERMOMETER MOUNTING BRACKETS

A. Description: Flanged bracket with screw holes, for attachment to air duct and made to hold thermometer stem.

2.3 THERMOWELLS

A. Thermowells:

1. Standard: ASME B40.200.
2. Description: Pressure-tight, socket-type fitting made for insertion into piping tee fitting.
3. Material for Use with Copper Tubing: CNR (copper nickel 90-10) .
4. Material for Use with Steel Piping: CRES (stainless steel) .
5. Type: Stepped shank unless straight or tapered shank is indicated.
6. External Threads: NPS 1/2, NPS 3/4, or NPS 1, (DN 15, DN 20, or NPS 25,) ASME B1.20.1 pipe threads.
7. Internal Threads: Size required to match thermometer bulb or stem, with ASME B1.1 screw threads.
8. Bore: Diameter required to match thermometer bulb or stem.
9. Insertion Length: Length required to match thermometer bulb or stem.
10. Lagging Extension: Include on thermowells for insulated piping and tubing.
11. Bushings: For converting size of thermowell's internal screw thread to size of thermometer connection.

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

2.4 TEST PLUGS

A. Basis-of-Design Product: Subject to compliance with requirements, provide Peterson Equipment Co., Inc.; Model 110 XL or comparable product by one of the following:

1. Sisco Manufacturing Company, Inc.
2. Trerice, H. O. Co.
3. Weiss Instruments, Inc.

B. Description: Test-station fitting made for insertion into piping tee fitting.

C. Body: Brass or stainless steel with core inserts and gasketed and threaded cap. Include extended stem on units to be installed in insulated piping.

D. Thread Size: NPS 1/4 (DN 8) , ASME B1.20.1 pipe thread.

E. Minimum Pressure and Temperature Rating: 500 psig at 200 deg F (3450 kPa at 93 deg C) .

F. Core Inserts: EPDM self-sealing rubber.

2.5 TEST-PLUG KITS

A. Basis-of-Design Product: Subject to compliance with requirements, provide Peterson Equipment Co., Inc.; Model 1500XL or comparable product by one of the following:

1. Miljoco Corporation.
2. Sisco Manufacturing Company, Inc.
3. Trerice, H. O. Co.
4. Weiss Instruments, Inc.

B. Furnish one test-plug kit(s) containing two thermometer(s), one pressure gage and adapter, and carrying case. Thermometer sensing elements, pressure gage, and adapter probes shall be of diameter to fit test plugs and of length to project into piping.

C. Low-Range Thermometer: Small, bimetallic insertion type with 1- to 2-inch- (25- to 51-mm-) diameter dial and tapered-end sensing element. Dial range shall be at least 25 to 125 deg F (minus 4 to plus 52 deg C) .

D. High-Range Thermometer: Small, bimetallic insertion type with 1- to 2-inch- (25- to 51-mm-) diameter dial and tapered-end sensing element. Dial range shall be at least 0 to 220 deg F (minus 18 to plus 104 deg C) .

E. Pressure Gage: Small, Bourdon-tube insertion type with 2- to 3-inch- (51- to 76-mm-) diameter dial and probe. Dial range shall be at least 0 to 200 psig (0 to 1380 kPa) .

F. Carrying Case: Metal or plastic, with formed instrument padding.

2.6 FLOWMETERS

A. Turbine Flowmeters:

1. Basis-of-Design Product: Subject to compliance with requirements, provide ONICON, Inc.; F-1211**;** or comparable product by one of the following:

    a. ABB; Instrumentation and Analytical.
    b. Data Industrial Corp.
    c. EMCO Flow Systems; a division of Spirax Sarco, Inc.

2. Description: Flowmeter with sensor and indicator.
3. Flow Range: Sensor and indicator shall cover operating range of equipment or system served.
4. Sensor: Impeller turbine; for inserting into pipe fitting or for installing in piping and measuring flow directly in gallons per minute (liters per second).

    a. Design: Device or pipe fitting with inline turbine and integral direct-reading scale for water.
    b. Construction: 316 stainless-steel body, with plastic turbine or impeller.
    c. Minimum Pressure Rating: 150 psig (1035 kPa).
5. Minimum Temperature Rating: 180 deg F (82 deg C)Indicator: Hand-held meter; either an integral part of sensor or a separate meter.
6. Accuracy: Plus or minus 1-1/2percent.
7. Display: Shows rate of flow, with register to indicate total volume in gallons (liters).
8. Operating Instructions: Include complete instructions with each flowmeter.

B. Venturi Flowmeters:

1. Basis-of-Design Product: Subject to compliance with requirements, provide Griswold Controls; 3Q??0T Metering Station or comparable product by one of the following:

    a. ABB; Instrumentation and Analytical.
    b. Gerand Engineering Co.

2. Description: Flowmeter with calibrated flow-measuring element, hoses or tubing, fittings, valves, indicator, and conversion chart.
3. Flow Range: Sensor and indicator shall cover operating range of equipment or system served.
4. Sensor: Venturi-type, calibrated, flow-measuring element; for installation in piping.

    a. Design: Differential-pressure-type measurement for water .
    b. Construction: Bronze, brass, or factory-primed steel, with brass fittings and attached tag with flow conversion data.
    c. Minimum Pressure Rating: 240 psig (1656 kPa).
    d. Minimum Temperature Rating: 250 deg F (121 deg C) .
    e. End Connections for NPS 2 (DN 50) and Smaller: Threaded.
    f. End Connections for NPS 2-1/2 (DN 65) and Larger: Flanged or welded.
    g. Flow Range: Flow-measuring element and flowmeter shall cover operating range of equipment or system served.

5. Portable Indicators: Hand-held, differential-pressure type, calibrated for connected flowmeter element and having two 12-foot (3.7-m) hoses, with carrying case.

    a. Scale: Gallons per minute (Liters per second).

b. Accuracy: Plus or minus 2 percent between 20 and 80 percent of scale range.

6. Display: Shows rate of flow, with register to indicate total volume in gallons (liters).
7. Conversion Chart: Flow rate data compatible with sensor.
8. Operating Instructions: Include complete instructions with each flowmeter.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install thermowells with socket extending a minimum of 2 inches (51 mm) into fluid and in vertical position in piping tees.

B. Install thermowells of sizes required to match thermometer connectors. Include bushings if required to match sizes.

C. Install thermowells with extension on insulated piping.

D. Fill thermowells with heat-transfer medium.

E. Install direct-mounted thermometers in thermowells and adjust vertical and tilted positions.

F. Install duct-thermometer mounting brackets in walls of ducts. Attach to duct with screws.

G. Assemble and install connections, tubing, and accessories between flow-measuring elements and flowmeters according to manufacturer's written instructions.

H. Install flowmeter elements in accessible positions in piping systems.

I. Install differential-pressure-type flowmeter elements, with at least minimum straight lengths of pipe, upstream and downstream from element according to manufacturer's written instructions.

J. Install connection fittings in accessible locations for attachment to portable indicators.

K. Install thermometers in the following locations:
1. Inlet and outlet of each hydronic coil in air-handling units.
2. Air handler supply air ducts with an airflow of 2000 cfm or greater.

L. Install test plugs in the following locations:

1. Inlet and outlet of each hydronic coil.
2. Inlet and outlet of each pressure independent control valve.

3.2 CONNECTIONS

A. Install meters and gages adjacent to machines and equipment to allow service and maintenance of meters, gages, machines, and equipment.

3.3 ADJUSTING

A. After installation, calibrate meters according to manufacturer's written instructions.

B. Adjust faces of meters and gages to proper angle for best visibility.

3.4 THERMOMETER SCHEDULE

A. Thermometers at inlet and outlet of each hydronic coil in air-handling units shall be the following:
   1. Industrial-style, liquid-in-glass type.
   2. Test plug with EPDM self-sealing rubber inserts shall be provided in addition to industrial or remote mounted thermometers.

B. Thermometers at supply-air ducts shall be the following:
   1. Industrial-style, liquid-in-glass type.

C. Thermometer stems shall be of length to match thermowell insertion length.

3.5 THERMOMETER SCALE-RANGE SCHEDULE

A. Scale Range for Chilled-Water Piping: 0 to 100 deg F (Minus 20 to plus 50 deg C) .

B. Scale Range for Heating, Hot-Water Piping: 20 to 240 deg F (0 to 150 deg C) .

C. Scale Range for Air Ducts: [**0 to 100 deg F (Minus 20 to plus 50 deg C)**] .

D. Scale Range for Air Ducts: 0 to 150 deg F (Minus 20 to plus 70 deg C) .

3.6 FLOWMETER SCHEDULE

A. Flowmeters for Chilled-Water Piping: Provide Venturi type as indicated on plans for testing, adjusting and balancing.

B. Flowmeters for Heating, Hot-Water Piping: Provide Venturi type as indicated on plans for testing, adjusting and balancing.

END OF SECTION 230519

SECTION 230523 - GENERAL-DUTY VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Bronze ball valves.
2. Iron, single-flange butterfly valves.

B. Related Sections:

1. Division 23 HVAC piping Sections for specialty valves applicable to those Sections only.
2. Division 23 Section "Identification for HVAC Piping and Equipment" for valve tags and schedules.

1.3 DEFINITIONS

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. RS: Rising stem.

G. SWP: Steam working pressure.

1.4 ACTION SUBMITTALS

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

1.5 QUALITY ASSURANCE

A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

B. ASME Compliance:

1. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
2. ASME B31.9 for building services piping valves.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Prepare valves for shipping as follows:

1. Protect internal parts against rust and corrosion.
2. Protect threads, flange faces, grooves, and weld ends.
3. Set gate valves closed to prevent rattling.
4. Set ball valves open to minimize exposure of functional surfaces.
5. Set butterfly valves closed or slightly open.

B. Use the following precautions during storage:

1. Maintain valve end protection.
2. Store valves indoors and maintain at higher than ambient dew point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.

C. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

A. Refer to HVAC valve schedule articles for applications of valves.

B. Valve Pressure and Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.

C. Valve Sizes: Same as upstream piping unless otherwise indicated.

D. Valve Actuator Types:
1. Handwheel: For valves other than quarter-turn types.
2. Handlever: For quarter-turn valves NPS 6 (DN 150) and smaller.

E. Valves in Insulated Piping: With 2-inch (50-mm) stem extensions and the following features:
1. Ball Valves: With 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: With extended neck.

F. Valve-End Connections:

1. Flanged: With flanges according to ASME B16.1 for iron valves.
2. Solder Joint: With sockets according to ASME B16.18.
3. Threaded: With threads according to ASME B1.20.1.

G. Valve Bypass and Drain Connections: MSS SP-45.

2.2 BRONZE BALL VALVES

A. Two-Piece, Full-Port, Bronze Ball Valves with Stainless-Steel Trim:

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

a. Conbraco Industries, Inc.; Apollo Valves.
b. Milwaukee Valve Company.
c. NIBCO INC.
d. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. Description:

a. Standard: MSS SP-110.
b. SWP Rating: 150 psig (1035 kPa).
c. CWP Rating: 600 psig (4140 kPa).
d. Body Design: Two piece.
e. Body Material: Bronze.
f. Ends: Threaded.
g. Seats: PTFE or TFE.
h. Stem: Stainless steel.
i. Ball: Stainless steel, vented.
j. Port: Full.

2.3 IRON, SINGLE-FLANGE BUTTERFLY VALVES

A. 150 CWP, Iron, Single-Flange Butterfly Valves with EPDM Seat and Aluminum-Bronze Disc:

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

a. Milwaukee Valve Company.
b. NIBCO INC.
c. Tyco Valves & Controls; a unit of Tyco Flow Control.
d. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. Description:

a. Standard: MSS SP-67, Type I.
b. CWP Rating: 150 psig (1035 kPa).

c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
d. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
e. Seat: EPDM.
f. Stem: One- or two-piece stainless steel.
g. Disc: Aluminum bronze.

B. 200 CWP, Iron, Single-Flange Butterfly Valves with EPDM Seat and Aluminum-Bronze Disc:

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

a. Milwaukee Valve Company.
b. NIBCO INC.
c. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. Description:

a. Standard: MSS SP-67, Type I.
b. CWP Rating: 200 psig (1380 kPa).
c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
d. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
e. Seat: EPDM.
f. Stem: One- or two-piece stainless steel.
g. Disc: Aluminum bronze.

PART 3 - EXECUTION

3.1 EXAMINATION

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

B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.

C. Examine threads on valve and mating pipe for form and cleanliness.

D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.

E. Do not attempt to repair defective valves; replace with new valves.

3.2 VALVE INSTALLATION

A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.

B. Locate valves for easy access and provide separate support where necessary.

C. Install valves in horizontal piping with stem at or above center of pipe.

D. Install valves in position to allow full stem movement.

3.3 ADJUSTING

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

3.4 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

A. If valve applications are not indicated, use the following:

1. Shutoff Service: Ball, butterfly valves.
2. Butterfly Valve Dead-End Service: Single-flange (lug) type.
3. Throttling Service: ball or butterfly valves.

B. If valves with specified SWP classes or CWP ratings are not available, the same types of valves with higher SWP classes or CWP ratings may be substituted.

C. Select valves, except wafer types, with the following end connections:

1. For Copper Tubing, NPS 2 (DN 50) and Smaller: Threaded ends except where solder-joint valve-end option is indicated in valve schedules below.
2. For Copper Tubing, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Flanged ends except where threaded valve-end option is indicated in valve schedules below.
3. For Copper Tubing, NPS 5 (DN 125) and Larger: Flanged ends.
4. For Steel Piping, NPS 2 (DN 50) and Smaller: Threaded ends.
5. For Steel Piping, NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Flanged ends except where threaded valve-end option is indicated in valve schedules below.

3.5 CHILLED-WATER VALVE SCHEDULE

A. Pipe NPS 2 (DN 50) and Smaller:
1. Ball Valves: Two piece, full port, bronze with stainless-steel trim.

B. Pipe NPS 2-1/2 (DN 65) and Larger:

1. Iron, Single-Flange Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): 200 CWP, EPDM seat, aluminum-bronze disc.

3.6 HEATING-WATER VALVE SCHEDULE

A. Pipe NPS 2 (DN 50) and Smaller:
   1. Ball Valves: Two piece, full port, bronze with stainless-steel trim.

B. Pipe NPS 2-1/2 (DN 65) and Larger:

   1. Iron, Single-Flange Butterfly Valves, NPS 2-1/2 to NPS 12 (DN 65 to DN 300): 200 CWP, EPDM seat, aluminum-bronze disc.

END OF SECTION 230523

SECTION 230529 - HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Metal pipe hangers and supports.
2. Trapeze pipe hangers.
3. Metal framing systems.
4. Fastener systems.
5. Equipment supports.

B. Related Sections:

1. Division 23 Section "Expansion Fittings and Loops for HVAC Piping" for pipe guides and anchors.
2. Division 23 Section "Vibration Controls for HVAC Piping and Equipment" for vibration isolation devices.
3. Division 23 Section(s) "Metal Ducts" for duct hangers and supports.

1.3 DEFINITIONS

A. MSS: Manufacturers Standardization Society of The Valve and Fittings Industry Inc.

1.4 ACTION SUBMITTALS

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

B. Shop Drawings: Show fabrication and installation details and include calculations for the following; include Product Data for components:

1. Trapeze pipe hangers.
2. Metal framing systems.
3. Equipment supports.

PART 2 - PRODUCTS

2.1 METAL PIPE HANGERS AND SUPPORTS

A. Carbon-Steel Pipe Hangers and Supports:

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

B. Copper Pipe Hangers:

1. Description: MSS SP-58, Types 1 through 58, copper-coated-steel, factory-fabricated components.
2. Hanger Rods: Continuous-thread rod, nuts, and washer made of copper-coated steel .

2.2 TRAPEZE PIPE HANGERS

A. Description: MSS SP-69, Type 59, shop- or field-fabricated pipe-support assembly made from structural carbon-steel shapes with MSS SP-58 carbon-steel hanger rods, nuts, saddles, and U-bolts.

2.3 METAL FRAMING SYSTEMS

A. MFMA Manufacturer Metal Framing Systems:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following :
   a. Cooper B-Line, Inc.
   b. Flex-Strut Inc.
   c. Unistrut Corporation; Tyco International, Ltd.

2. Description: Shop- or field-fabricated pipe-support assembly for supporting multiple parallel pipes.
3. Standard: MFMA-4.
4. Channels: Continuous slotted steel channel with inturned lips.
5. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
6. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel .
7. Metallic Coating: Electroplated zinc .

B. Non-MFMA Manufacturer Metal Framing Systems:

1. Description: Shop- or field-fabricated pipe-support assembly made of steel channels, accessories, fittings, and other components for supporting multiple parallel pipes.
2. Standard: Comply with MFMA-4.

3. Channels: Continuous slotted steel channel with inturned lips.
4. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
5. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel .
6. Coating: Zinc.

2.4 FASTENER SYSTEMS

A. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

B. Mechanical-Expansion Anchors: Insert-wedge-type, zinc-coated steel anchors, for use in hardened portland cement concrete; with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

2.5 EQUIPMENT SUPPORTS

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

2.6 MISCELLANEOUS MATERIALS

A. Structural Steel: ASTM A 36/A 36M, carbon-steel plates, shapes, and bars; black and galvanized.

B. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.

1. Properties: Nonstaining, noncorrosive, and nongaseous.
2. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT INSTALLATION

A. Metal Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.

B. Metal Trapeze Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Arrange for grouping of parallel runs of horizontal piping, and support together on field-fabricated trapeze pipe hangers.

1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified for individual pipe hangers.

2. Field fabricate from ASTM A 36/A 36M, carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.

C. Metal Framing System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled metal framing systems.

D. Fastener System Installation:

1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches (100 mm) thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.
2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

E. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.

F. Equipment Support Installation: Fabricate from welded-structural-steel shapes.

G. Install hangers and supports to allow controlled thermal movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.

H. Install lateral bracing with pipe hangers and supports to prevent swaying.

I. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 (DN 65) and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

J. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.

K. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.

L. Insulated Piping:

1. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.

2. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.

3. Shield Dimensions for Pipe: Not less than the following:

a. NPS 1/4 to NPS 3-1/2 (DN 8 to DN 90): 12 inches (305 mm) long and 0.048 inch (1.22 mm) thick.
b. NPS 4 (DN 100): 12 inches (305 mm) long and 0.06 inch (1.52 mm) thick.

c. NPS 5 and NPS 6 (DN 125 and DN 150): 18 inches (457 mm) long and 0.06 inch (1.52 mm) thick.

4. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

3.2 EQUIPMENT SUPPORTS

A. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.

B. Grouting: Place grout under supports for equipment and make bearing surface smooth.

C. Provide lateral bracing, to prevent swaying, for equipment supports.

3.3 METAL FABRICATIONS

A. Cut, drill, and fit miscellaneous metal fabrications for equipment supports.

B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.

C. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:

1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
2. Obtain fusion without undercut or overlap.
3. Remove welding flux immediately.
4. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

3.4 ADJUSTING

A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.

B. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches (40 mm) .

3.5 PAINTING

A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.

1. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils (0.05 mm).

B. Touchup: Cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal are specified in Division 09 painting Sections.

C. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

3.6 HANGER AND SUPPORT SCHEDULE

A. Specific hanger and support requirements are in Sections specifying piping systems and equipment.

B. Comply with MSS SP-69 for pipe-hanger selections and applications that are not specified in piping system Sections.

C. Use hangers and supports with galvanized metallic coatings for piping and equipment that will not have field-applied finish.

D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

E. Use carbon-steel pipe hangers and supports metal trapeze pipe hangers and metal framing systems and attachments for general service applications.

F. Use copper-plated pipe hangers and copper attachments for copper piping and tubing.

G. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated, stationary pipes NPS 1/2 to NPS 30 (DN 15 to DN 750).
2. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes NPS 1/2 to NPS 24 (DN 15 to DN 600) if little or no insulation is required.
3. Pipe Saddle Supports (MSS Type 36): For support of pipes NPS 4 to NPS 36 (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate.
4. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes NPS 2-1/2 to NPS 24 (DN 65 to DN 600), from single rod if horizontal movement caused by expansion and contraction might occur.
5. Complete Pipe Rolls (MSS Type 44): For support of pipes NPS 2 to NPS 42 (DN 50 to DN 1050) if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.

H. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers NPS 3/4 to NPS 24 (DN 24 to DN 600).

I. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.

J. Comply with MSS SP-69 for trapeze pipe-hanger selections and applications that are not specified in piping system Sections.

K. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.

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

END OF SECTION 230529

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SECTION 230548 - VIBRATION CONTROLS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes the following:

1. Isolation pads.
2. Isolation mounts.
3. Freestanding spring isolators.
4. Elastomeric hangers.
5. Spring hangers.

1.3 DEFINITIONS

A. IBC: International Building Code.

B. ICC-ES: ICC-Evaluation Service.

C. OSHPD: Office of Statewide Health Planning and Development for the State of California.

1.4 ACTION SUBMITTALS

A. Product Data: For the following:

1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.

1.5 QUALITY ASSURANCE

A. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

PART 2 - PRODUCTS

2.1 VIBRATION ISOLATORS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Amber/Booth Company, Inc.
2. Kinetics Noise Control.
3. Mason Industries.

B. Pads : Arranged in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.

1. Resilient Material: Oil- and water-resistant neoprene .

C. Mounts: Double-deflection type, with molded, oil-resistant rubber, hermetically sealed compressed fiberglass, or neoprene isolator elements with factory-drilled, encapsulated top plate for bolting to equipment and with baseplate for bolting to structure. Color-code or otherwise identify to indicate capacity range.

1. Materials: Cast-ductile-iron or welded steel housing containing two separate and opposing, oil-resistant rubber or neoprene elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.
2. Neoprene: Shock-absorbing materials compounded according to the standard for bridge-bearing neoprene as defined by AASHTO.

D. Spring Isolators: Freestanding, laterally stable, open-spring isolators.

1. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
2. Minimum Additional Travel: 50 percent of the required deflection at rated load.
3. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
4. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
5. Baseplates: Factory drilled for bolting to structure and bonded to 1/4-inch- (6-mm-) thick, rubber isolator pad attached to baseplate underside. Baseplates shall limit floor load to 500 psig (3447 kPa).
6. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

E. Elastomeric Hangers: Single or double-deflection type, fitted with molded, oil-resistant elastomeric isolator elements bonded to steel housings with threaded connections for hanger rods. Color-code or otherwise identify to indicate capacity range.

F. Spring Hangers: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression.

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

2.2 FACTORY FINISHES

A. Finish: Manufacturer's standard paint applied to factory-assembled and -tested equipment before shipping.

1. Powder coating on springs and housings.
2. All hardware shall be galvanized. Hot-dip galvanize metal components for exterior use.
3. Baked enamel or powder coat for metal components on isolators for interior use.
4. Color-code or otherwise mark vibration isolation -control devices to indicate capacity range.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and equipment to receive vibration isolation -control devices for compliance with requirements for installation tolerances and other conditions affecting performance.

B. Examine roughing-in of reinforcement and cast-in-place anchors to verify actual locations before installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 VIBRATION-CONTROL DEVICE INSTALLATION

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

B. Drilled-in Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are

encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.

2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
5. Set anchors to manufacturer's recommended torque, using a torque wrench.
6. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

3.3 ADJUSTING

A. Adjust isolators after piping system is at operating weight.

B. Adjust active height of spring isolators.

END OF SECTION 230548

SECTION 230553 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Equipment labels.
2. Warning signs and labels.
3. Pipe labels.
4. Valve tags.
5. Warning tags.

1.3 ACTION SUBMITTALS

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

B. Equipment Label Schedule: Include a listing of all equipment to be labeled with the proposed content for each label.

C. Valve numbering scheme.

D. Valve Schedules: For each piping system to include in maintenance manuals.

1.4 COORDINATION

A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.

B. Coordinate installation of identifying devices with locations of access panels and doors.

C. Install identifying devices before installing acoustical ceilings and similar concealment.

PART 2 - PRODUCTS

2.1 EQUIPMENT LABELS

A. Plastic Labels for Equipment:

1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch (3.2 mm) thick, and having predrilled holes for attachment hardware.
2. Letter Color: White .
3. Background Color: Black .
4. Maximum Temperature: Able to withstand temperatures up to 160 deg F (71 deg C).
5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch (64 by 19 mm).
6. Minimum Letter Size: 1/4 inch (6.4 mm) for name of units if viewing distance is less than 24 inches (600 mm), 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
7. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

B. Label Content: Include equipment's Drawing designation or unique equipment number, Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified.

2.2 WARNING SIGNS AND LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch (3.2 mm) thick, and having predrilled holes for attachment hardware.

B. Letter Color: White

C. Background Color: Black

D. Maximum Temperature: Able to withstand temperatures up to 160 deg F (71 deg C).

E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch (64 by 19 mm).

F. Minimum Letter Size: 1/4 inch (6.4 mm) for name of units if viewing distance is less than 24 inches (600 mm), 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

G. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

H. Label Content: Include caution and warning information, plus emergency notification instructions.

2.3 PIPE LABELS

A. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction.

B. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to cover full circumference of pipe and to attach to pipe without fasteners or adhesive.

C. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings, pipe size, and an arrow indicating flow direction.

1. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions, or as separate unit on each pipe label to indicate flow direction.
2. Lettering Size: At least 1-1/2 inches (38 mm) high.

2.4 VALVE TAGS

A. Valve Tags: Stamped or engraved with 1/4-inch (6.4-mm) letters for piping system abbreviation and 1/2-inch (13-mm) numbers.

1. Tag Material: Brass, 0.032-inch (0.8-mm) minimum thickness, and having predrilled or stamped holes for attachment hardware.
2. Fasteners: Brass wire-link or beaded chain; or S-hook .

B. Valve Schedules: For each piping system, on 8-1/2-by-11-inch (A4) bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.

1. Valve-tag schedule shall be included in operation and maintenance data.

2.5 WARNING TAGS

A. Warning Tags: Preprinted or partially preprinted, accident-prevention tags, of plasticized card stock with matte finish suitable for writing.

1. Size: 3 by 5-1/4 inches (75 by 133 mm) minimum .
2. Fasteners: Brass grommet and wire .
3. Nomenclature: Large-size primary caption such as "DANGER," "CAUTION," or "DO NOT OPERATE."
4. Color: Yellow background with black lettering.

PART 3 - EXECUTION

3.1 PREPARATION

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

3.2 EQUIPMENT LABEL INSTALLATION

A. Install or permanently fasten labels on each major item of mechanical equipment.

B. Locate equipment labels where accessible and visible.

3.3 PIPE LABEL INSTALLATION

A. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of 50 feet (15 m) along each run. Reduce intervals to 25 feet (7.6 m) in areas of congested piping and equipment.
7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

B. Pipe Label Color Schedule:

1. Chilled-Water Piping:

   a. Background Color: Blue
   b. Letter Color: White

2. Heating Water Piping:

   a. Background Color: Yellow
   b. Letter Color: Black

3.4 VALVE-TAG INSTALLATION

A. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; shutoff valves; faucets; convenience and lawn-watering hose connections; and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.

B. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs:

1. Valve-Tag Size and Shape:

   a. Chilled Water: 1-1/2 inches (38 mm) , round.

2. Hot Water: 1-1/2 inches (38 mm) , round Valve-Tag Color:

   a. Chilled Water: Natural.
   b. Hot Water: Natural.

3.5 WARNING-TAG INSTALLATION

A. Write required message on, and attach warning tags to, equipment and other items where required.

END OF SECTION 230553

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SECTION 230593 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Balancing Air Systems:

a. Constant-volume air systems.
b. Variable-air-volume systems.

2. Balancing Hydronic Piping Systems:

a. Constant-flow hydronic systems.
b. Variable-flow hydronic systems.
c. Primary-secondary hydronic systems.

1.3 DEFINITIONS

A. AABC: Associated Air Balance Council.

B. NEBB: National Environmental Balancing Bureau.

C. TAB: Testing, adjusting, and balancing.

D. TABB: Testing, Adjusting, and Balancing Bureau.

E. TAB Specialist: An entity engaged to perform TAB Work.

1.4 ACTION SUBMITTALS

1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: Within 15 days of Contractor's Notice to Proceed, submit documentation that the TAB contractor and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.

B. Contract Documents Examination Report: Within 30 days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.

C. Strategies and Procedures Plan: Within 30 days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.

D. Certified TAB reports.

E. Sample report forms.

F. Instrument calibration reports, to include the following:

1. Instrument type and make.
2. Serial number.
3. Application.
4. Dates of use.
5. Dates of calibration.

1.6 QUALITY ASSURANCE

A. TAB Contractor Qualifications: Engage a TAB entity certified by AABC NEBB or TABB.

1. TAB Field Supervisor: Employee of the TAB contractor and certified by AABC NEBB or TABB.
2. TAB Technician: Employee of the TAB contractor and who is certified by AABC NEBB or TABB as a TAB technician.

B. TAB Conference: Meet with Owner on approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Require the participation of the TAB field supervisor and technicians. Provide seven days' advance notice of scheduled meeting time and location.

1. Agenda Items:

a. The Contract Documents examination report.
b. The TAB plan.
c. Coordination and cooperation of trades and subcontractors.
d. Coordination of documentation and communication flow.

C. Certify TAB field data reports and perform the following:

1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
2. Certify that the TAB team complied with the approved TAB plan and the procedures specified and referenced in this Specification.

D. TAB Report Forms: Use standard TAB contractor's forms approved by Engineer.

E. Instrumentation Type, Quantity, Accuracy, and Calibration: As described in ASHRAE 111, Section 5, "Instrumentation."

F. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."

G. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

1.7 PROJECT CONDITIONS

A. Partial Owner Occupancy: Owner may occupy completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

1.8 COORDINATION

A. Notice: Provide seven days' advance notice for each test. Include scheduled test dates and times.

B. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 EXAMINATION

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

B. Examine systems for installed balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are accessible.

C. Examine the approved submittals for HVAC systems and equipment.

D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine ceiling plenums used for supply, return, or relief air to verify that they meet the leakage class of connected ducts as specified in Division 23 Section "Metal Ducts " and are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.

F. Examine equipment performance data including fan and pump curves.

1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.

G. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.

H. Examine test reports specified in individual system and equipment Sections.

I. Examine HVAC equipment and filters and verify that bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

J. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.

K. Examine strainers. Verify that startup screens are replaced by permanent screens with indicated perforations.

L. Examine three-way valves for proper installation for their intended function of diverting or mixing fluid flows.

M. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

N. Examine system pumps to ensure absence of entrained air in the suction piping.

O. Examine operating safety interlocks and controls on HVAC equipment.

P. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.2 PREPARATION

A. Prepare a TAB plan that includes strategies and step-by-step procedures.

B. Complete system-readiness checks and prepare reports. Verify the following:

1. Permanent electrical-power wiring is complete.
2. Hydronic systems are filled, clean, and free of air.
3. Automatic temperature-control systems are operational.
4. Equipment and duct access doors are securely closed.
5. Balance, smoke, and fire dampers are open.
6. Isolating and balancing valves are open and control valves are operational.
7. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.

8. Windows and doors can be closed so indicated conditions for system operations can be met.

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in ASHRAE 111 SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing" and in this Section.

1. Comply with requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.
1. After testing and balancing, install test ports and duct access doors that comply with requirements in Division 23 Section "Air Duct Accessories."
2. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Division 23 Section "HVAC Insulation."

C. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.

D. Take and report testing and balancing measurements in inch-pound (IP) units.

3.4 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.

B. Prepare schematic diagrams of systems' "as-built" duct layouts.

C. For variable-air-volume systems, develop a plan to simulate diversity.

D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.

E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.

F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

G. Verify that motor starters are equipped with properly sized thermal protection.

H. Check dampers for proper position to achieve desired airflow path.

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

K. Check for proper sealing of air-handling-unit components.

L. Verify that air duct system is sealed as specified in Division 23 Section "Metal Ducts."

3.5 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure total airflow.

    a. Where sufficient space in ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow.

2. Measure fan static pressures as follows to determine actual static pressure:

    a. Measure outlet static pressure as far downstream from the fan as practical and upstream from restrictions in ducts such as elbows and transitions.
    b. Measure static pressure directly at the fan outlet or through the flexible connection.
    c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.
    d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

3. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.

    a. Report the cleanliness status of filters and the time static pressures are measured.

4. Measure static pressures entering and leaving other devices, such as sound traps, heat-recovery equipment, and air washers, under final balanced conditions.
5. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
6. Obtain approval from Engineer for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in Division 23 Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
7. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.

1. Measure airflow of submain and branch ducts.

a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.

2. Measure static pressure at a point downstream from the balancing damper, and adjust volume dampers until the proper static pressure is achieved.
3. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure air outlets and inlets without making adjustments.

1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.

D. Adjust air outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using branch volume dampers rather than extractors and the dampers at air terminals.

1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
2. Adjust patterns of adjustable outlets for proper distribution without drafts.

3.6 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

A. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a minimum set-point airflow with the remainder at maximum-airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.

B. Pressure-Independent, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set outdoor-air dampers at minimum, and set return- and exhaust-air dampers at a position that simulates full-cooling load.
2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
3. Measure total system airflow. Adjust to within indicated airflow.
4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.

a. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.

6. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

   a. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.
8. Record final fan-performance data.

3.7 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports with pertinent design data, and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against the approved pump flow rate. Correct variations that exceed plus or minus 5 percent.

B. Prepare schematic diagrams of systems' "as-built" piping layouts.

C. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:

1. Open all manual valves for maximum flow.
2. Check liquid level in expansion tank.
3. Check makeup water-station pressure gage for adequate pressure for highest vent.
4. Check flow-control valves for specified sequence of operation, and set at indicated flow.
5. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type unless several terminal valves are kept open.
6. Set system controls so automatic valves are wide open to heat exchangers.
7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.8 PROCEDURES FOR CONSTANT-FLOW HYDRONIC SYSTEMS

A. Measure water flow at pumps. Use the following procedures except for positive-displacement pumps:

1. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.

a. If impeller sizes must be adjusted to achieve pump performance, obtain approval from Engineer and comply with requirements in Division 23 Section "Hydronic Pumps."

2. Check system resistance. With all valves open, read pressure differential across the pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until indicated water flow is achieved.

a. Monitor motor performance during procedures and do not operate motors in overload conditions.

3. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.
4. Report flow rates that are not within plus or minus 10 percent of design.

B. Measure flow at all automatic flow control valves to verify that valves are functioning as designed.

C. Measure flow at all pressure-independent characterized control valves, with valves in fully open position, to verify that valves are functioning as designed.

D. Set calibrated balancing valves, if installed, at calculated presettings.

E. Measure flow at all stations and adjust, where necessary, to obtain first balance.

1. System components that have Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.

F. Measure flow at main balancing station and set main balancing device to achieve flow that is 5 percent greater than indicated flow.

G. Adjust balancing stations to within specified tolerances of indicated flow rate as follows:

1. Determine the balancing station with the highest percentage over indicated flow.
2. Adjust each station in turn, beginning with the station with the highest percentage over indicated flow and proceeding to the station with the lowest percentage over indicated flow.
3. Record settings and mark balancing devices.

H. Measure pump flow rate and make final measurements of pump amperage, voltage, rpm, pump heads, and systems' pressures and temperatures including outdoor-air temperature.

I. Measure the differential-pressure-control-valve settings existing at the conclusion of balancing.

J. Check settings and operation of each safety valve. Record settings.

3.9 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

A. Balance systems with automatic two- and three-way control valves by setting systems at maximum flow through heat-exchange terminals and proceed as specified above for hydronic systems.

3.10 PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS

A. Balance the primary circuit flow first and then balance the secondary circuits.

3.11 PROCEDURES FOR MOTORS

A. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:

1. Manufacturer's name, model number, and serial number.
2. Motor horsepower rating.
3. Motor rpm.
4. Efficiency rating.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter thermal-protection-element rating.

B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass of the controller to prove proper operation. Record observations including name of controller manufacturer, model number, serial number, and nameplate data.

3.12 PROCEDURES FOR HEAT-TRANSFER COILS

A. Measure, adjust, and record the following data for each water coil:

1. Entering- and leaving-water temperature.
2. Water flow rate.
3. Water pressure drop.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.
7. Air pressure drop.

3.13 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

A. Perform a preconstruction inspection of existing equipment that is to remain and be reused.

1. Measure and record the operating speed, airflow, and static pressure of each fan.
2. Measure motor voltage and amperage. Compare the values to motor nameplate information.
3. Check bearings and other lubricated parts for proper lubrication.

4. Report on the operating condition of the equipment and the results of the measurements taken. Report deficiencies.

B. Before performing testing and balancing of existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished. Verify the following:
   1. Bearings and other parts are properly lubricated.
   2. Deficiencies noted in the preconstruction report are corrected.

C. Perform testing and balancing of existing systems to the extent that existing systems are affected by the renovation work.
   1. If calculations increase or decrease the water flow rates by more than 5 percent, make equipment adjustments to achieve the calculated rates. If increase or decrease is 5 percent or less, equipment adjustments are not required.

3.14 TOLERANCES

A. Set HVAC system's air flow rates and water flow rates within the following tolerances:

   1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus or minus 10 percent .
   2. Air Outlets and Inlets: Plus or minus 10 percent.
   3. Heating-Water Flow Rate: Plus or minus 10 percent.
   4. Cooling-Water Flow Rate: Plus or minus 10 percent .

3.15 REPORTING

A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems' balancing devices. Recommend changes and additions to systems' balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Status Reports: Prepare weekly progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.16 FINAL REPORT

A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

   1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
   2. Include a list of instruments used for procedures, along with proof of calibration.

B. Final Report Contents: In addition to certified field-report data, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance; do not include Shop Drawings and product data.

C. General Report Data: In addition to form titles and entries, include the following data:

1. Title page.
2. Name and address of the TAB contractor.
3. Project name.
4. Project location.
5. Engineer's name and address.
6. Contractor's name and address.
7. Report date.
8. Signature of TAB supervisor who certifies the report.
9. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
10. Summary of contents including the following:

    a. Indicated versus final performance.
    b. Notable characteristics of systems.
    c. Description of system operation sequence if it varies from the Contract Documents.

11. Nomenclature sheets for each item of equipment.
12. Data for terminal units, including manufacturer's name, type, size, and fittings.
13. Notes to explain why certain final data in the body of reports vary from indicated values.
14. Test conditions for fans and pump performance forms including the following:

    a. Settings for outdoor-, return-, and exhaust-air dampers.
    b. Conditions of filters.
    c. Cooling coil, wet- and dry-bulb conditions.
    d. Fan drive settings including settings and percentage of maximum pitch diameter.
    e. Settings for supply-air, static-pressure controller.
    f. Other system operating conditions that affect performance.

D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:

1. Quantities of outdoor, supply, return, and exhaust airflows.
2. Water flow rates.
3. Duct, outlet, and inlet sizes.
4. Pipe and valve sizes and locations.
5. Terminal units.
6. Balancing stations.
7. Position of balancing devices.

E. Air-Handling-Unit Test Reports: For air-handling units with coils, include the following:

1. Unit Data:

    a. Unit identification.
    b. Location.
    c. Make and type.
    d. Model number and unit size.
    e. Manufacturer's serial number.
    f. Unit arrangement and class.
    g. Discharge arrangement.
    h. Sheave make, size in inches (mm), and bore.
    i. Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).
    j. Number, make, and size of belts.
    k. Number, type, and size of filters.

2. Motor Data:

    a. Motor make, and frame type and size.
    b. Horsepower and rpm.
    c. Volts, phase, and hertz.
    d. Full-load amperage and service factor.
    e. Sheave make, size in inches (mm), and bore.
    f. Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).

3. Test Data (Indicated and Actual Values):

    a. Total air flow rate in cfm (L/s).
    b. Total system static pressure in inches wg (Pa).
    c. Fan rpm.
    d. Discharge static pressure in inches wg (Pa).
    e. Filter static-pressure differential in inches wg (Pa).
    f. Preheat-coil static-pressure differential in inches wg (Pa).
    g. Cooling-coil static-pressure differential in inches wg (Pa).
    h. Heating-coil static-pressure differential in inches wg (Pa).
    i. Outdoor airflow in cfm (L/s).
    j. Return airflow in cfm (L/s).
    k. Outdoor-air damper position.
    l. Return-air damper position.

F. Apparatus-Coil Test Reports:

1. Coil Data:

    a. System identification.
    b. Location.
    c. Coil type.
    d. Number of rows.
    e. Fin spacing in fins per inch (mm) o.c.
    f. Make and model number.
    g. Face area in sq. ft. (sq. m).
    h. Tube size in NPS (DN).
    i. Tube and fin materials.

j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm (L/s).
b. Average face velocity in fpm (m/s).
c. Air pressure drop in inches wg (Pa).
d. Outdoor-air, wet- and dry-bulb temperatures in deg F (deg C).
e. Return-air, wet- and dry-bulb temperatures in deg F (deg C).
f. Entering-air, wet- and dry-bulb temperatures in deg F (deg C).
g. Leaving-air, wet- and dry-bulb temperatures in deg F (deg C).
h. Water flow rate in gpm (L/s).
i. Water pressure differential in feet of head or psig (kPa).
j. Entering-water temperature in deg F (deg C).
k. Leaving-water temperature in deg F (deg C).

G. Fan Test Reports: For supply and exhaust fans, include the following:

1. Fan Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and size.
e. Manufacturer's serial number.
f. Arrangement and class.
g. Sheave make, size in inches (mm), and bore.
h. Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).

2. Motor Data:

a. Motor make, and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches (mm), and bore.
f. Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).
g. Number, make, and size of belts.

3. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm (L/s).
b. Total system static pressure in inches wg (Pa).
c. Fan rpm.
d. Discharge static pressure in inches wg (Pa).
e. Suction static pressure in inches wg (Pa).

H. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

a. System and air-handling-unit number.
b. Location and zone.
c. Traverse air temperature in deg F (deg C).
d. Duct static pressure in inches wg (Pa).
e. Duct size in inches (mm).
f. Duct area in sq. ft. (sq. m).
g. Indicated air flow rate in cfm (L/s).
h. Indicated velocity in fpm (m/s).
i. Actual air flow rate in cfm (L/s).
j. Actual average velocity in fpm (m/s).
k. Barometric pressure in psig (Pa).

I. Air-Terminal-Device Reports:

1. Unit Data:

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

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm (L/s).
b. Air velocity in fpm (m/s).
c. Preliminary air flow rate as needed in cfm (L/s).
d. Preliminary velocity as needed in fpm (m/s).
e. Final air flow rate in cfm (L/s).
f. Final velocity in fpm (m/s).
g. Space temperature in deg F (deg C).

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

1. Unit Data:

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

2. Test Data (Indicated and Actual Values):

a. Air flow rate in cfm (L/s).
b. Entering-water temperature in deg F (deg C).
c. Leaving-water temperature in deg F (deg C).

d. Water pressure drop in feet of head or psig (kPa).
e. Entering-air temperature in deg F (deg C).
f. Leaving-air temperature in deg F (deg C).

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

1. Unit Data:

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

2. Test Data (Indicated and Actual Values):

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

L. Instrument Calibration Reports:

1. Report Data:

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

3.17 INSPECTIONS

A. Initial Inspection:

1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the final report.
2. Check the following for each system:

a. Measure airflow of at least 10 percent of air outlets.
b. Measure water flow of at least 5 percent of terminals.
c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.
d. Verify that balancing devices are marked with final balance position.
e. Note deviations from the Contract Documents in the final report.

B. Final Inspection:

1. After initial inspection is complete and documentation by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by Engineer .
2. The TAB contractor's test and balance engineer shall conduct the inspection in the presence of Engineer .
3. Engineer shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.
4. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
5. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

C. TAB Work will be considered defective if it does not pass final inspections. If TAB Work fails, proceed as follows:

1. Recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
2. If the second final inspection also fails, Owner may contract the services of another TAB contractor to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB contractor's final payment.

D. Prepare test and inspection reports.

3.18 ADDITIONAL TESTS

A. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

END OF SECTION 230593

SECTION 230713 - DUCT INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes insulating the following duct services:

1. Indoor, concealed supply, return and outdoor air.
2. Indoor, exposed supply, return and outdoor air.
3. Indoor, concealed exhaust between isolation damper and penetration of building exterior.
4. Indoor, exposed exhaust between isolation damper and penetration of building exterior.

1.3 ACTION SUBMITTALS

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

1.4 INFORMATIONAL SUBMITTALS

A. Qualification Data: For qualified Installer.

B. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.

1.5 QUALITY ASSURANCE

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

B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.

2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

1.6 DELIVERY, STORAGE, AND HANDLING

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

1.7 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with duct Installer for duct insulation application. Before preparing ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

1.8 SCHEDULING

A. Schedule insulation application after pressure testing systems . Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

A. Comply with requirements in "Duct Insulation Schedule, General," "Indoor Duct and Plenum Insulation Schedule," articles for where insulating materials shall be applied.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

F. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, Type III with factory-applied FSK jacket . Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

G. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB. For duct and plenum applications, provide insulation with factory-applied FSK jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

2.2 ADHESIVES

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

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

1. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.3 MASTICS

A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.

1. For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below ambient services.

1. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm (0.009 metric perm) at 43-mil (1.09-mm) dry film thickness.
2. Service Temperature Range: Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C).
3. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
4. Color: White.

2.4 SEALANTS

A. FSK and Metal Jacket Flashing Sealants:

1. Materials shall be compatible with insulation materials, jackets, and substrates.
2. Fire- and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C).
4. Color: Aluminum.
5. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.5 FACTORY-APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
   1. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.

2.6 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

2.7 TAPES

A. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.

   1. Width: 3 inches (75 mm).
   2. Thickness: 6.5 mils (0.16 mm).
   3. Adhesion: 90 ounces force/inch (1.0 N/mm) in width.
   4. Elongation: 2 percent.
   5. Tensile Strength: 40 lbf/inch (7.2 N/mm) in width.
   6. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

2.8 SECUREMENTS

A. Insulation Pins and Hangers:

   1. Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated.

   2. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) galvanized carbon-steel washer.

   3. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm-) thick, galvanized-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.

      a. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.

B. Staples: Outward-clinching insulation staples, nominal 3/4-inch- (19-mm-) wide, stainless steel or Monel.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.

1. Verify that systems to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

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

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of ducts and fittings.

B. Install insulation materials, vapor barriers or retarders, jackets, and thicknesses required for each item of duct system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Keep insulation materials dry during application and finishing.

G. Install insulation with least number of joints practical.

H. Seal penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.

I. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

J. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

K. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches (100 mm) beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

3.4 PENETRATIONS

A. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

B. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches (50 mm).

1. Comply with requirements in Division 07 Section "Penetration Firestopping"irestopping and fire-resistive joint sealers.

3.5 INSTALLATION OF MINERAL-FIBER INSULATION

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

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 50 percent coverage of duct and plenum surfaces.
2. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

    a. On duct sides with dimensions 18 inches (450 mm) and smaller, place pins along longitudinal centerline of duct. Space 3 inches (75 mm) maximum from insulation end joints, and 16 inches (400 mm) o.c.
    b. On duct sides with dimensions larger than 18 inches (450 mm), place pins 16 inches (400 mm) o.c. each way, and 3 inches (75 mm) maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
    c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
    d. Do not overcompress insulation during installation.
    e. Impale insulation over pins and attach speed washers.
    f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

3. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches (50 mm) from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch (13-mm) outward-clinching staples, 1 inch (25 mm) o.c. Install vapor barrier consisting of factory- or field-

applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
b. Install vapor stops for ductwork and plenums operating below 50 deg F (10 deg C) at 18-foot (5.5-m) intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches (75 mm).

4. Overlap unfaced blankets a minimum of 2 inches (50 mm) on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches (450 mm) o.c.
5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- (150-mm-) wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches (150 mm) o.c.

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

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 50 percent coverage of duct and plenum surfaces.
2. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

a. On duct sides with dimensions 18 inches (450 mm) and smaller, place pins along longitudinal centerline of duct. Space 3 inches (75 mm) maximum from insulation end joints, and 16 inches (400 mm) o.c.
b. On duct sides with dimensions larger than 18 inches (450 mm), space pins 16 inches (400 mm) o.c. each way, and 3 inches (75 mm) maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
d. Do not overcompress insulation during installation.
e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

3. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches (50 mm) from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch (13-mm) outward-clinching staples, 1 inch (25 mm) o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
b. Install vapor stops for ductwork and plenums operating below 50 deg F (10 deg C) at 18-foot (5.5-m) intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches (75 mm).

4. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
5. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- (150-mm-) wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches (150 mm) o.c.

3.6 DUCT INSULATION SCHEDULE, GENERAL

A. Plenums and Ducts Requiring Insulation:

1. Indoor, concealed supply, return and outdoor air.
2. Indoor, exposed supply, return and outdoor air.
3. Indoor, concealed exhaust between isolation damper and penetration of building exterior.
4. Indoor, exposed exhaust between isolation damper and penetration of building exterior.

B. Items Not Insulated:
1. Factory-insulated flexible ducts.
2. Factory-insulated plenums and casings.
3. Flexible connectors.
4. Vibration-control devices.
5. Factory-insulated access panels and doors.

3.7 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Concealed, supply-air duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

B. Concealed, return-air and outdoor duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

C. Concealed, rectangular, outdoor-air duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

D. Concealed, rectangular, exhaust-air duct insulation between isolation damper and penetration of building exterior shall be one of the following:

1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

E. Concealed, supply-air plenum insulation shall be the following:
1. Mineral-Fiber Board: 2 inches (50 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

F. Concealed, return-air, outdoor air and exhaust airplenum insulation shall be the following:
1. Mineral-Fiber Board: 2 inches (50 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

G. Exposed, supply-air duct insulation shall be the following:
1. Mineral-Fiber Board: 2 inches (50 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

H. Exposed, return-air, outdoor air and exhaust air duct insulation shall be the following:
1. Mineral-Fiber Board: 2 inches (50 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

I. Exposed, supply-air plenum insulation shall be the following:
1. Mineral-Fiber Board: 2 inches (50 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

J. Exposed, return-air, outdoor air and exhaust air plenum insulation shall be the following:
1. Mineral-Fiber Board: 2 inches (50 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.

END OF SECTION 230713

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SECTION 230719 - HVAC PIPING INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes insulating the following HVAC piping systems:

1. Condensate drain piping, indoors .
2. Chilled-water piping, indoors .
3. Heating hot-water piping, indoors .

B. Related Sections:

1. Division 23 Section "HVAC Equipment Insulation."

1.3 ACTION SUBMITTALS

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

1.4 QUALITY ASSURANCE

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

B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

1.5 DELIVERY, STORAGE, AND HANDLING

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

1.6 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with piping Installer for piping insulation application.

1.7 SCHEDULING

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

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

A. Comply with requirements in "Piping Insulation Schedule, General," "Indoor Piping Insulation Schedule," articles for where insulating materials shall be applied.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

F. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Block Insulation: ASTM C 552, Type I.
2. Special-Shaped Insulation: ASTM C 552, Type III.
3. Board Insulation: ASTM C 552, Type IV.
4. Preformed Pipe Insulation with Factory-Applied ASJ-SSL: Comply with ASTM C 552, Type II, Class 2.

5. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.

G. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials.

H. Mineral-Fiber, Preformed Pipe Insulation:

1. Type I, 850 deg F (454 deg C) Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

2.2 INSULATING CEMENTS

A. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C 449.

2.3 ADHESIVES

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

B. Cellular-Glass Adhesive: Two-component, thermosetting urethane adhesive containing no flammable solvents, with a service temperature range of minus 100 to plus 200 deg F (minus 73 to plus 93 deg C).

1. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. Flexible Elastomeric Adhesive: Comply with MIL-A-24179A, Type II, Class I.

1. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

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

1. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

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

1. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.4 MASTICS

A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.

1. For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below-ambient services.

1. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm (0.009 metric perm) at 43-mil (1.09-mm) dry film thickness.
2. Service Temperature Range: Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C).
3. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
4. Color: White.

C. Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.

1. Water-Vapor Permeance: ASTM F 1249, 1.8 perms (1.2 metric perms) at 0.0625-inch (1.6-mm) dry film thickness.
2. Service Temperature Range: Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C).
3. Solids Content: 60 percent by volume and 66 percent by weight.
4. Color: White.

2.5 LAGGING ADHESIVES

A. Description: Comply with MIL-A-3316C, Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.

1. For indoor applications, use lagging adhesives that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over pipe insulation.
3. Service Temperature Range: 0 to plus 180 deg F (Minus 18 to plus 82 deg C).
4. Color: White.

2.6 SEALANTS

A. Joint Sealants:

1. Materials shall be compatible with insulation materials, jackets, and substrates.
2. Permanently flexible, elastomeric sealant.

3. Service Temperature Range: Minus 100 to plus 300 deg F (Minus 73 to plus 149 deg C).
4. Color: White or gray.
5. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

B. Metal Jacket Flashing Sealants:

1. Materials shall be compatible with insulation materials, jackets, and substrates.
2. Fire- and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C).
4. Color: Aluminum.
5. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

C. ASJ Flashing Sealants:

1. Materials shall be compatible with insulation materials, jackets, and substrates.
2. Fire- and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C).
4. Color: White.
5. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.7 FACTORY-APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
1. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.

2.8 FIELD-APPLIED FABRIC-REINFORCING MESH

A. Woven Glass-Fiber Fabric: Approximately 2 oz./sq. yd. (68 g/sq. m) with a thread count of 10 strands by 10 strands/sq. in. (4 strands by 4 strands/sq. mm) for covering pipe and pipe fittings.

2.9 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

B. Metal Jacket:

1. Aluminum Jacket: Comply with ASTM B 209 (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005, Temper H-14.
   a. Finish and thickness are indicated in field-applied jacket schedules.
   b. Moisture Barrier for Indoor Applications: 1-mil- (0.025-mm-) thick, heat-bonded polyethylene and kraft paper .
   c. Moisture Barrier for Outdoor Applications: 2.5-mil- (0.063-mm-) thick polysurlyn.
   d. Factory-Fabricated Fitting Covers:
      1) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

2.10 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.

1. Width: 3 inches (75 mm).
2. Thickness: 11.5 mils (0.29 mm).
3. Adhesion: 90 ounces force/inch (1.0 N/mm) in width.
4. Elongation: 2 percent.
5. Tensile Strength: 40 lbf/inch (7.2 N/mm) in width.
6. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

2.11 SECUREMENTS

A. Bands:

1. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 304 ; 0.015 inch (0.38 mm) thick, 1/2 inch (13 mm) wide with wing seal .
2. Aluminum: ASTM B 209 (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch (0.51 mm) thick, 1/2 inch (13 mm) wide with wing seal .

B. Wire: 0.062-inch (1.6-mm) soft-annealed, stainless steel .

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.

1. Verify that systems to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

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

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

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping including fittings, valves, and specialties.

B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of pipe system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Keep insulation materials dry during application and finishing.

G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

H. Install insulation with least number of joints practical.

I. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.

J. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

K. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.

2. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
3. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.

L. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

M. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches (100 mm) beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

N. For above-ambient services, do not install insulation to the following:

1. Vibration-control devices.
2. Testing agency labels and stamps.
3. Nameplates and data plates.

3.4 PENETRATIONS

A. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

B. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions.

1. Comply with requirements in Division 07 Section "Penetration Firestopping" for firestopping and fire-resistive joint sealers.

3.5 GENERAL PIPE INSULATION INSTALLATION

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

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

1. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.
2. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
3. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
4. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement. For above ambient systems provide manufactured reusable insulation covers; for below ambient systems provide field fabricated removable insulation covers.

5. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.
6. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
7. For services not specified to receive a field-applied jacket except for flexible elastomeric, install fitted cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with end caps. Secure covers to adjoining insulation facing.
8. Stencil or label the outside insulation jacket of each union with the word "union." Match size and color of pipe labels.

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

D. Field Fabricated Removable Insulation Covers: Install field fabricated removable insulation covers at unions, control valves, valves and other locations indicated for below ambient systems. Installation shall maintain continuous vapor barrier and conform to the following:

1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as adjoining pipe insulation.
2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless-steel or aluminum bands. Select band material compatible with insulation and jacket.
3. Construct removable valve insulation covers in same manner as for flanges, except divide the two-part section on the vertical center line of valve body.
4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless-steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches (50 mm) over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish. Finish exposed surfaces with a metal jacket.

3.6 INSTALLATION OF CELLULAR-GLASS INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Create a water stop between insulation and pipe by brushing vapor barrier mastic on pipe around circumference of pipe every 3 feet..
2. On below-ambient services, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with insulating cement and flashing sealant.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch (25 mm), and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

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

D. Insulation Installation on Valves and Pipe Specialties:

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

3.7 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

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

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as pipe insulation.
4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install mitered sections of pipe insulation.
2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed valve covers manufactured of same material as pipe insulation when available.
2. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
3. Install insulation to flanges as specified for flange insulation application.
4. Secure insulation to valves and specialties and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.8 INSTALLATION OF MINERAL-FIBER INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of preformed pipe insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
2. For insulation with factory-applied jackets on above-ambient surfaces, secure laps with outward-clinched staples at 6 inches (150 mm) o.c.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch (25 mm), and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

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

D. Insulation Installation on Valves and Pipe Specialties:

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

3.9 FIELD-APPLIED JACKET INSTALLATION

A. Where metal jackets are indicated, install with 2-inch (50-mm) overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands 12 inches (300 mm) o.c. and at end joints.

3.10 FINISHES

A. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.

B. Color: Final color as selected by Engineer. Vary first and second coats to allow visual inspection of the completed Work.

C. Do not field paint aluminum or stainless-steel jackets.

3.11 PIPING INSULATION SCHEDULE, GENERAL

A. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.

3.12 INDOOR PIPING INSULATION SCHEDULE

A. Condensate and Equipment Drain Water below 60 Deg F (16 Deg C):

1. All Pipe Sizes: Insulation shall be the following:
   a. Flexible Elastomeric: 3/4 inch (19 mm) thick.

B. Chilled Water:

1. NPS 3 (DN 80) and Smaller: Insulation shall be one of the following:

   a. Cellular Glass: 2 inches (50 mm) thick.

2. NPS 4 and Larger: Insulation shall be one of the following:

   a. Cellular Glass: 3 inches (75 mm) thick.

C. Heating-Hot-Water Supply and Return, 200 Deg F (93 Deg C) and Below:

1. All Pipe Sizes: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe, Type I: 2 inches (50 mm) thick.

3.13 INDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.

C. Piping, Concealed:

1. None.

D. Piping, Exposed:

1. Aluminum, Corrugated : 0.016 inch (0.41 mm) thick.

END OF SECTION 230719

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230910 INSTRUMENTATION AND CONTROLS FOR HVAC SYSTEM

1.0 GENERAL

1.1 Related Sections:

The General Conditions of the Contract, Supplementary Conditions, and General Requirements are part of this specification and shall be used in conjunction with this section as part of the contract documents.

A. The following sections constitute related work:
   1. 230513 Common Motor Requirements for HVAC Equipment
   2. 230593 Testing, Adjusting, and Balancing for HVAC
   3. 230993 Sequence of Operations for BAS Controls
   4. 232113 Hydronic Piping
   5. 233300 Air Duct Accessories

1.2 Definitions / Abbreviations:

A. BAS – Building Automation System

B. BC – Building Controller; Programmable controller with input/output points residing on peer-to-peer or high level building network.

C. AAC – Advanced Application Controller; Programmable controller serving single piece of equipment and residing on peer to peer or high level building network.

D. ASC – Application Specific Controller; Pre-programmed controller with specific routines for applicable equipment and residing on lower level or sub-LAN network connected to a BC.

E. LAN – Local area network

F. Router – Device connecting two or more communication networks utilizing the same application protocol.

G. Gateway – Device connecting two or more communication networks utilizing different application protocol.

1.3 Scope / Description:

A. The intent of this specification is to provide a complete and operational BAS designed to accomplish the intent of the sequences of operation specified herein.

B. Supplementary Conditions, applicable provisions of Division 23, General Requirements, and other provisions and requirements of the contract documents apply to work in this section.

C. Electrical Work: Furnish all control wiring, conduit, relays, contactors and electrical work required as integral part of the BAS or indicated on mechanical drawings.

1. Control contractor shall provide relays and/or contactors required for operation of single phase motors, 1 hp and smaller. Motor starters for three phase motors and single phase motors larger than 1 hp shall be furnished and installed by Division 26 contractor.

D. Mechanical Work: Furnish all wells for water monitoring devices, flow switches and alarms, sensors, etc. to mechanical contractor for installation.

E. BAS System: The BAS manufacturer shall furnish and install a fully integrated INSTRUMENTATION AND CONTROLS SYSTEM, incorporating direct digital control (DDC) for energy management, equipment monitoring and control, and subsystems with open communications capabilities as herein specified.

1. Compatibility: The BAS system shall have a documented history of compatibility by design for a minimum of 15 years. Future compatibility shall be supported for no less than 10 years. Compatibility shall be defined as the ability to upgrade existing field panels to current level of technology, and extend new field panels on a previously installed network. Compatibility shall be defined as the ability for any existing field panel microprocessor to be connected and directly communicate with new field panels without bridges, routers or protocol converters.

2. Architecture: System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. Each DDC Controller shall operate independently by performing its own specified control, alarm management, operator I/O, and data collection. The failure of any single component or network connection shall not interrupt the execution of any control strategy, reporting, alarming and trending function, or any function at any operator interface device.

3. DDC Controllers shall be able to access any data from, or send control commands and alarm reports directly to, any other DDC Controller or combination of controllers on the network without dependence upon a central or intermediate processing device. DDC Controllers shall also be able to send alarm to multiple operator workstations without dependence upon a central or intermediate processing device.

4. The system shall be scalable in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, DDC Controllers, and operator devices.

5. Spare Capacity: Building Controllers and Advanced Application Controllers shall be selected to provide a minimum of 10% spare I/O point capacity for each point type found at each location. If input points are not universal, 10% of each type is required. If outputs are not universal, 10% of each type is required. A minimum of one spare is required for each type of point used. DDC controllers shall have sufficient internal memory for the specified control sequences and trend logging. There shall be a minimum of 25% of available memory free for future use. Future use of spare capacity shall require providing the field device, field wiring, points database definition, and custom software. No additional

Controller boards or point modules shall be required to implement use of these spare points.

6. All real time clocks and data file RAM shall battery back-up for a minimum 72 hours and include local and system low battery indication. Provide a UPS, capable of powering the end device for a minimum of 4 hours, for workstation(s) and building controllers.

7. Provide surge transient protection for all DDC controllers and operator workstations.

8. Provide static, transient and short-circuit protection on all inputs and outputs. Protect communication lines against incorrect wiring, static transients and induced magnetic interference.

9. Provide satisfactory operation without damage at 110% and 85% of rated voltage and at plus 3 Hertz variation in line frequency.

10. The BAS system specified herein is an expansion of an existing BAS system manufactured by Johnson Controls . The existing system does not utilize BACnet network protocols.

11. Communications:

    a. Communication between building controllers and all operator/server workstations shall be over a high-speed Ethernet network using standard TCP/IP, IEEE 802.3 protocol. All nodes on this network shall be peers. The operator shall not have to identify the panel or address to view or control an object. AACs and ASCs shall be constantly scanned by their respective BC to update point and alarm information.

    b. Building Level Networks shall be connected to the existing server workstation located in the current location via the owner's Ethernet backbone network as specified herein.

    c. Provide system capable of interoperability with the existing operator interface as specified herein.

    d. The system shall be capable of supporting wireless field level networks or sensor communications using a mesh topology and IEEE 802.15.4 network.

F. Abbreviations, Symbols and Definitions: All letter symbols and engineering unit abbreviations utilized in information displays and printouts shall be fully explained and documented in the documentation provided.

G. System Commissioning: The control contractor shall include within his bid price an allowance for 8 hours of time to meet with the design engineer for the purpose of commissioning the system as described in Section 3.19 of this specification. The control contractor shall provide a designated representative familiar with the specific building system as installed to meet with the engineer at

the jobsite at the time of substantial completion. Time for the design engineer shall be charged at $160.00 per hour, and billed directly to the control contractor from the design engineer.

1.4 Work by Others:

A. Products furnished by control contractor but installed by mechanical contractor:

1. Control Valves
2. Electronic Actuators
3. Control Dampers
4. Flow Meters
5. Air Flow Stations
6. Thermal Wells and Sockets
7. Taps and Tap Isolation Valves
8. The control supplier shall provide to the variable volume terminal unit manufacturer the static pressure transmitter, damper actuator, fan control relay, transformer and application specific controller for factory mounting to the boxes prior to shipment to the project.

B. Products furnished and installed by mechanical contractor but wired by electrical contractor:

1. Adjustable Frequency Drives

C. Products furnished and installed by mechanical or electrical contractor, but integrated to by control contractor:

1. Fire Alarm System via Hardwire
2. Smoke Detectors via Hardwire
3. Adjustable Frequency Drives via BACnet MS/TP
4. Control Dampers via Hardwire

D. Electrical Contractor:

1. Wiring of power feeds through all disconnects or starters to electrical motors.
2. Wiring of any remote start/stop switches and manual or automatic motor speed control devices not furnished by control contractor.
3. Wiring of any electrical sub-metering devices furnished by control contractor.

1.5 Approved manufacturers:

A. The following list of approved manufacturers applies to controller software, custom application programming language, building controllers, advanced application controllers, and application specific controllers.

Manufacturer

Johnson Controls

All other products specified herein and elsewhere in Division 23 specifications are not required to be manufactured by the above manufacturer.

1.6 Quality Assurance:

A. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the specification requirements. All systems and components shall have been thoroughly tested and proven in actual use for at least two years or as approved by the engineer.

B. The installation of the control system shall be performed under the direct supervision of the controls manufacturer with the shop drawings, flow diagrams, bill of materials, component designation or identification number and sequence of operation all bearing the name of the manufacturer. The installing manufacturer shall certify in writing, that the shop drawings have been prepared by the equipment manufacturer and that the equipment manufacturer has supervised their installation. In addition, the equipment manufacturer shall certify, in writing, that the shop drawings were prepared by their company and that all temperature control equipment was installed under their direct supervision.

C. Contractor Qualifications: The control system shall be designed and installed, commissioned and serviced by manufacturer employed, factory trained personnel. BAS contractor shall have an in-place support facility within 100 miles of the site with technical staff, spare parts inventory and necessary test and diagnostic equipment. Distributors or licensed installing contractors are not acceptable. The BAS contractor shall provide full time, on site, experienced project manager for this work, responsible for direct supervision of the design, installation, start up and commissioning of the BAS system.

D. Testing and Adjustment: Upon completion of the project, the control contractor shall completely adjust or calibrate, ready for use, all thermostats, sensors, transducers, valves, damper operators, relays, etc., provided under this specification.

E. Point-to-Point Testing: Provide testing and adjustment of the complete Control System. Validate every control point to its respective control panel or controller and to the Operator Interface at the existing location. Test all connected devices so that the displayed controlled variable is within plus or minus one percent of the actual sampled variable.

F. Certification: Furnish a letter from the control system manufacturer stating that the system is properly installed and operating as designed.

1.7 Codes and Standards:

A. The manufacturer of the INSTRUMENTATION AND CONTROLS SYSTEM shall provide documentation supporting compliance with ISO-9002 (Model for Quality Assurance in Production, Installation, and Servicing) and ISO-140001 (The application of well-accepted business management principles to the environment).

B. All computing devices, as defined in FCC Rules and Regulations, Part 15, shall be verified to comply with the requirements for Class A computing devices and labeled as set-forth in FCC Rules and Regulations, Part 15.

C. All peer-to-peer network controllers, central system controllers, and local user displays shall be UL Listed under Standard UL 916, category PAZX; Standard ULC C100, category UUKL7; and under Standard UL 864, categories UUKL, UDTZ, and QVAX and be so listed at the time of bid. All floor level controllers shall comply, at a minimum, with UL Standard UL 91 6category PAZX; Standard UL 864, categories UDTZ, and QVAX and be so listed at the time of Bid.

D. All wireless devices shall conform to the following:

1. The requirements of Title 47 of the Code of Federal Regulations FCC Part 15 governing radio frequency intentional radiating devices and be issued a FCC user identification and be so labeled.
2. CE Directive 1999/5/EC (Radio Equipment and Telecommunications Terminal Equipment and the Mutual Recognition of their Conformity).

E. The control system shall comply with the most restrictive requirements of all applicable standards and codes (including those listed below), except when more detailed or stringent requirements are indicated by the Contract Documents.

1. NFPA 70 - National Electric Code
2. IEEE 802.3 – Ethernet Standard

1.8 System Performance:

A. General: System shall perform to the following minimum standards over network connections and shall be tested using manufacturer's recommended hardware and software for operator workstation or server and browser for web-based systems.

B. Graphic Display: The system shall display a graphic with a minimum of 20 dynamic points with all current data within 10 seconds. System shall be capable of displaying up to 400 dynamic points per graphic.

C. Graphic Refresh: The system shall update all a graphic with 20 dynamic points with current data within 8 seconds and shall automatically refresh every 15 seconds.

D. Object Command: The maximum time between the command of a binary object by the operator and the reaction by the device shall be less than 10 seconds. Analog objects shall start to adjust within 10 seconds.

E. Object Scan: All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or workstation will have been current within the previous 60 seconds.

F. Alarm Response Time: The maximum time from when an object goes into alarm to when it is annunciated at the workstation shall not exceed 15 seconds.

G. Program Execution Frequency: Custom and standard applications shall be capable of running as often as once every 5 seconds. The control contractor shall be responsible for selecting execution times consistent with the mechanical process under control.

H. Performance: Programmable controllers shall be able to execute DDC PID control loops at a selectable frequency of at least once per second. The contractor shall select execution times consistent with the process under control. The controller shall scan and update the process value and output generated by this calculation at this same frequency.

I. Multiple Alarm Annunciation: All workstations on the network shall receive alarms within 5 seconds of each other.

J. Reporting Accuracy: The system shall report all values with a minimum end-to-end accuracy as listed below:

Measured Variable	**Reported Accuracy**
Space temperature	±1°F
Ducted air	±2°F
Outside air	±2°F
Water temperature	±1°F
Delta-T	±0.25°F
Relative humidity	±2% RH
Water flow	±5% of full scale
Air flow (terminal)	±10% of reading *Note 1
Air flow (measuring stations)	±5% of reading
Air pressure (ducts)	±0.1 "W.G.
Air pressure (space)	±0.01 "W.G.
Water pressure	±2% of full scale *Note 2
Electrical Power	5% of reading *Note 3
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO_2)	±50 PPM

Note 1: (10%-100% of scale) (cannot read accurately below 10%)
Note 2: For both absolute and differential pressure
Note 3: Not including utility supplied meters

K. Stability of Control: Control loops shall maintain measured variable at set point within the tolerances listed below:

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±0.2 in. w.g.	0-6 in w.g.
	±0.01 in. w.g.	-0.1 to 0.1 in. w.g.
Airflow	±10% of full scale	
Space Temperature	±2.0°F	
Duct Temperature	±3°F	
Humidity	±5% RH	
Fluid Pressure	±1.5 psi	1-150 psi
	±1.0 in. w.g.	0-50 in. w.g.

1.9 Submittals:

A. The contractor shall provide the following included in a submittal booklet. Each booklet shall be an 8-1/2" X 11" loose-leaf 3-ring binder with identification inserts in clear vinyl on the front cover and the back spine. Identification insert shall include building name, owner, controls contractor, design engineer and submittal date. Provide separate sections with the following tabbed dividers.

1. TAB 1 “System Schematics” – Provide the following: sequence of operations, object names, point addresses, interface wiring diagrams, panel layouts, and system riser diagrams (architecture). Schematics shall be submitted in 11" X 17" format. Also provide in AutoCAD v2004 drawing format on optical disk in binder pocket.

2. TAB 2 “Object List” – Provide object lists in 8 ½” x 11” format. Object list shall include for each physical or logical point, the name, description, display units, BACnet object description, object ID, associated device ID, address, object type (AO, AI, DI, DO), initial value, default value, reset limits, alarm high and low limits. Coordinate object names and addresses with system schematics. Also provide in Excel file format on optical disk in binder pocket.

3. Tab 3 “HVAC Plans” – HVAC plans in 11”x17” format indicating controlled equipment, control panel and sensor locations.

4. Tab 4 “Object Naming Convention” - Indicate the format, structure and standards of typical point names. Provide a list of point names for typical equipment and functions with specific coordinated examples. The addressing scheme shall be coordinated and approved by the owner and engineer.

5. Tab 5 “Valve & Damper Schedule” – Provide valve and damper schedules showing size, configuration, CV, system pressures, capacity and location of all equipment.

6. TAB 6 “TAB Data” – Empty

7. TAB 7 “System Verification Checklists” – Empty

8. TAB 8 “Functional Performance Tests” – Empty

9. TAB 9 “Bill of Materials – A complete bill of materials of equipment to be used indicating quantity, manufacturer, model number and relevant technical data.

10. TAB 10 “Data Sheets” – Provide for all control system components. When manufacturer has cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawing shall clearly reference the specification and/or drawing that the submittal is being submitted to cover.

    a. Provide PICS files indicating the BACnet functionality and configuration of each device. In addition to the requirements of BACnet, Annex A,

provide information on any limitations on the numbers of supported objects in a given device including, specifically, trend log and schedule projects.

b. Provide documentation on submitted products that have been tested and listed by the BACnet Testing Laboratory (BTL) or a letter on manufacturer's company letterhead indicating the anticipated date by which testing is expected to be completed. If, for any reason, BTL testing and listing has not been completed, a written commitment shall be provided to upgrade installed controls to a version that meets BTL testing and listing requirements should deficiencies be found during BTL testing.

11. TAB 11 "O&M" – Operation and maintenance manuals for each controller, valve, damper, meter or any other device or piece of equipment. O&M manuals shall be specific to the product used for this project and shall specifically identifying the actual product and options used and only contain O&M information pertaining to said product. Submittal of a general series of products is not acceptable. In addition to O&M manuals, the BAS contractor shall provide an executive summary at the front end of the tabbed section. The executive summary should outline the type and location of specific items that require routine maintenance or calibration (i.e., CO_2 sensors) and the general procedure for performing said work.

12. TAB 12 "Training" – Description of process, report formats and checklists to be used in Part 3: "Control System Demonstration and Acceptance."

13. TAB 13 "Service Contacts" - Names, addresses, and 24-hour telephone numbers of local factory direct service representatives for equipment and control systems.

1.10 Record Documents:

A. The contractor shall provide three copies of the following included in an operation and maintenance manual for the use of the owner's operating personnel. Each manual shall be an 8-1/2" X 11" loose-leaf 3-ring binder with identification inserts in clear vinyl on the front cover and the back spine. Identification insert shall include building name, owner, controls contractor, design engineer, commissioning authority and commissioning date. Provide separate sections with the following tabbed dividers. Each of the following shall incorporate as-built data derived from the commissioning process.

1. TAB 1 "System Schematics" – Approved submittals Indicating as-built conditions. Also provide in AutoCAD v2004 drawing format on optical disk in binder pocket.

2. TAB 2 "Object List" – Approved submittals Indicating final object names, setpoints, reset limits, alarm high and low limits, default values, etc. Object list shall also identify. Also provide in Excel file format on optical disk in binder pocket.

3. Tab 3 "HVAC Plans" – As-built version of submitted HVAC plans in 11"x17" format indicating controlled equipment, control panel and sensor locations.

4. TAB 4 “Valve & Damper Schedule” – Approved submittals

5. Tab 5 “Object Naming Convention” – Approved submittals

6. TAB 6 “TAB Data” – Spread sheet format indicating final flow coefficients for each air flow monitoring station and water meter.

7. TAB 7 “System Verification Checklists” – Signed and dated by the installing contractor. This documentation shall include point-to-point verification specified herein and test measurements and system calibrations specified herein. A certification report shall be provided listing the test.

8. TAB 8 “Functional Performance Tests” – Copies of FPT forms completed and approved by the commissioning authority and as required to meet requirements of Part 3: “Control System Verification, Demonstration and Acceptance.”

9. TAB 9 “Bill of Materials – Approved submittals

10. TAB 10 “Data Sheets” – Approved submittals

11. TAB 11 “O&M” – Operation and maintenance manuals for each controller, valve, damper, meter or any other device or piece of equipment. O&M manuals shall be specific to the product used for this project and shall specifically identifying the actual product and options used and only contain O&M information pertaining to said product. Submittal of a general series of products is not acceptable. At minimum, provide the following.

    a. An executive summary at the front end of the tabbed section. The executive summary should outline the type and location of specific items that require routine maintenance or calibration (i.e., CO_2 sensors) and the general procedure for performing said work.

    b. Operator’s Manual with procedures for operating control systems, logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing set points and variables.

    c. Programming manual or set of manuals with description of programming language and of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.

    d. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.

e. Documentation of all programs created using custom programming language, including set points, tuning parameters, and object database.

f. Programs and database on optical media.

g. List of recommended spare parts with part numbers and suppliers.

h. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware, including computer equipment and sensors.

12. TAB 12 "Training" – Training videos specified herein on DVD format.

13. TAB 13 "Service Contacts" - Names, addresses, and 24-hour telephone numbers of local factory direct service representatives for equipment and control systems.

14. Tab 14 "Warranty" - Licenses, guarantees, and warranty documents for equipment and systems.

1.11 Training:

A. Provide the services of competent instructors who will give full instruction to designated personnel in the operation and maintenance of the Control System. Orient the training specifically to the system installed. Instructors shall be thoroughly familiar with the subject matter they are to teach. Provide a training manual for each student at each training phase that describes in detail the data included in each training program. Provide one additional copy for archiving.

B. Training Program: Accomplish the training program as specified. Conduct training at the site at a time mutually agreeable between the owner's representative and the contractor prior to final acceptance.

1.12 Warranty:

A. Labor & materials for control system specified shall be warranted free from defects for a period of twelve (12) months after final completion acceptance by the Owner. Control System failures during the warranty period shall be adjusted, repaired, or replaced at no charge or reduction in service to the Owner. The Contractor shall respond to the Owner's request for warranty service within 24 hours during customary business hours.

B. At the end of the final start-up/testing, if equipment and systems are operating satisfactorily to the Owner and Engineer, the Owner shall sign certificates certifying that the control system's operation has been tested and accepted in accordance with the terms of this specification. The date of Owner's acceptance shall be the start of warranty with qualified factory trained technician(s) within four (4) hours of verbal or written service request 24 hours a day, 7 days a week, 365 day a year including holidays and weekends.

1. Extended Warranty: Provide alternate pricing along with project warranty letter to extend all provisions of first year warranty for an additional two (2) years.

C. Operator workstation software, project specific software, graphics, database, and firmware updates shall be provided to the Owner at no charge during the warranty period. Written authorization by Owner must, however, be granted prior to the installation of such changes.

1.13 Ownership of Proprietary Material:

A. All project developed hardware and software shall become the property of the Owner. These include but are not limited to:

1. Project specific graphic images
2. Record drawings
3. Project specific database
4. Project specific application programming code
5. All project documentation

2.0 PRODUCTS

2.1 Materials:

A. All products used in this project installation shall be new and currently under manufacture and shall have been applied in similar installations for a minimum of two years. This installation shall not be used as a test site for any new products unless explicitly approved by the owner in writing. Spare parts shall be available for at least five years after completion of this contract.

B. Provide temperature control products in the size and capacities indicated, 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 the application indicated.

C. Where two units of the same type of equipment are required, these units shall be products of a single manufacturer. Each major component of equipment shall have the manufacturer's name and address and the model and serial number in a conspicuous place.

2.2 Communications:

A. Device Requirements: Devices supplied to meet the functional and operational requirements of this specification shall conform, at a minimum, device profiles specified herein.

B. Network Topology: The network topology (architecture) shall consist of the following levels:

1. Management Level Network: Ethernet based high speed data link between standard client and server workstations.

2. Peer-to-Peer Primary Building Level Network: Ethernet based high speed data link between building controllers, advanced application controllers, servers and operator workstations.

3. Master-Slave Secondary Sub-Networks: Moderate speed data link between application specific controllers and associated building controller.

C. Management Level Network: Devices on the Management Level Network shall communicate over Ethernet utilizing standard TCP/IP, IEEE 802.3.

1. Client workstations shall direct connect to the Ethernet Management Level Network without the use of an interposing device. Servers and Operator Workstations shall be capable of simultaneous direct connection and communication with TCP/IP level networks without the use of interposing devices. The Management Level Network shall not impose a maximum constraint on the number of connected workstations.

2. Any workstation on the Management Level Network shall have transparent communication with controllers on the building level networks connected via Ethernet.

3. Any break in Ethernet communication from a workstation to the controllers on the building level networks shall result in a notification at the workstation. Any break in Ethernet communication between the standard client workstations and servers on the Management Level Network shall result in a notification at each workstation.

4. System software applications will run as a service to allow communication with Building Level Network Controllers without the need for user log in. Closing the application or logging off shall not prevent the processing of alarms, network status, panel failures, and trend information.

5. Access to the system database shall be available from any standard client workstation on the Management Level Network.

6. Client access to client-server workstation configurations over the Internet network shall be available via Web browser interface.

7. Thin Client access to client-server workstation configurations via Windows Terminal Services shall provide multiple, independent sessions of the workstations software. Terminal Services clients shall have full functionality, without the need to install the workstation software on the local hard drive.

D. Primary Building Level Network: Devices on the Building Level Network shall communicate using Ethernet.

1. Operator Workstations, Server Workstations, All Building Controllers and Advanced Application Controllers shall directly reside on the building level Ethernet network such that communications may be executed directly between Building Controllers and directly between server, Building Controllers and Advanced Application Controllers on a peer-to-peer basis. Systems that operate via polled response or other types of protocols that rely on a central processor,

file server, or similar device to manage panel-to-panel or device-to-device communications shall not be acceptable.

2. This Building Level Network shall be connected to the owner's backbone network (Management Level Network). Unless otherwise specified, the connection shall be via a 10/100BASE-T port provided by the Owner. The location of the jack shall be coordinated with the owner's IT department. The Contractor shall also provide any additional data communication hardware, such as hubs and repeaters, which may be needed to interconnect the supplied BAS equipment and to connect to the Owner's backbone network.

3. All operator interfaces shall have the ability to access all point status and application report data or execute control functions for any and all other devices. Access to data shall be based upon logical identification of building equipment. No hardware or software limits shall be imposed on the number of devices with global access to the network data.

4. All devices on the building level network shall:

   a. Auto-sense 10/100 Mbps networks.

   b. Receive an IP Address from a Dynamic Host Configuration Protocol (DHCP) Server or be configured with a Fixed IP Address.

   c. Resolve Name to IP Addresses for devices using a Domain Name Service (DNS) Server on the Ethernet network.

5. The building level network shall provide the following minimum performance:

   a. Provide high-speed data transfer rates for alarm reporting, report generation from multiple controllers and upload/download efficiency between network devices. System performance shall insure that an alarm occurring at any controller is displayed at any PC workstations, all Building controllers, and other alarm printers within 15 seconds.

   b. Message and alarm buffering to prevent information from being lost.

   c. Error detection, correction, and re-transmission to guarantee data integrity.

   d. The building level network shall allow the Building Controllers to access any data from, or send control commands and alarm reports directly to, any other Building Controller or combination of controllers on the network without dependence upon a central or intermediate processing device. Building Controllers shall send alarm reports to multiple operator workstations without dependence upon a central or intermediate processing device.

The network shall also allow any Building controller to access, edit, modify, add, delete, back up, restore all system point database and all programs.

e. The building level network shall allow the Building Controllers to assign password access and control priorities to each point individually. The logon password (at any PC workstation or portable operator terminal) shall enable the operator to monitor, adjust and control only the points that the operator is authorized for. All other points shall not be displayed at the PC workstation or portable terminal. (e.g. all base building and all tenant points shall be accessible to any base building operators, but only certain base building and tenant points shall be accessible to tenant building operators). Passwords and priorities for every point shall be fully programmable and adjustable.

f. Devices containing custom programming must reside on the Building Level Network and shall be provided with non-volatile memory.

E. Secondary Sub-Network: Devices on sub-networks shall communicate using network protocol. .

1. Sub-networks shall support a family of application specific controllers for terminal equipment.

2. The Application Specific Controllers shall communicate bi-directionally with the building level network through Building Controllers for transmission of global data.

3. A maximum of 30 terminal equipment controllers shall be configured on individual sub- network trunks to insure adequate global data and alarm response times.

4. Where indicated communication over the secondary sub-network may utilize wireless MESH topology based on IEEE 802.15.4 network. Point to point communication shall be acceptable.

F. Provide all communication media, connectors, repeaters, hubs, routers and gateways necessary for the internet work and as necessary for communication with third party equipment control systems.

1. Router Requirements: In the event that devices are provided that do not use BACnet/IP over Ethernet or BACnet MS/TP as their communication technology, BACnet routers shall be provided that route between BACnet/IP or BACnet MS/TP and the other BACnet LAN type(s). These routers shall conform to the specifications of BACnet, Clause 6. The use of BACnet LAN types other than those specified herein for each network requires the specific approval of the Owner and Engineer.

2. Gateways: Devices that use BACnet as their native protocol are preferred. The use of gateways, in circumstances where no native BACnet device is available, requires the specific approval of the Owner and Engineer.

G. Communication services over the internet work shall result in operator interface and value passing that is transparent to the internet work architecture as follows:

1. Connection of an operator interface device to any one controller on the internet work will allow the operator to interface with all other controllers as if that interface were directly connected to the other controllers. Data, status information, reports, system software, custom programs, etc., for all controllers shall be available for viewing and editing from any one controller on the internet work.

2. All database values (e.g., objects, software, variables, custom program variables) of any one controller shall be readable by any other controller on the internet work. This value passing shall be automatically performed by a controller when a reference to an object name not located in that controller is entered into the controller's database. An operator/installer shall not be required to set up any communication services to perform internet work value passing.

H. The time clocks in all controllers shall be automatically synchronized daily via the internet work. An operator change to the time clock in any controller shall be automatically broadcast to all controllers on the internet work. System shall automatically adjust for daylight saving and standard time.

I. Portable Operator Interface: All controllers shall have a communication port for connections with a portable operator interface. Communication shall support memory downloads and other commissioning and troubleshooting operations.

J. Remote Notification Paging System: Workstations shall be configured to send out messages to numeric pagers, alphanumeric pagers, phones (via text to speech technology), SMS (Simple Messaging Service, text messaging) Devices, and email accounts based on a point's alarm condition.`

1. There shall be no limit to the number of points that can be configured for remote notification of alarm conditions and no limit on the number of remote devices which can receive messages from the system.

2. On a per point basis, system shall be configurable to send messages to an individual or group and shall be configurable to send different messages to different remote devices based on alarm message priority level.

3. Remote devices may be scheduled as to when they receive messages from the system to account for operators' work schedules.

4. System must be configurable to send messages to an escalation list so that if the first device does not respond, the message is sent on to the next device after a configurable time has elapsed.

5. Message detail shall be configurable on a per user basis.

6. During a "flood" of alarms, remote notification messages shall have the ability to optimize several alarms into an individual remote notification message.

7. Workstation shall have the ability to send manual messages allowing an operator to type in a message to be sent immediately.

8. Workstation shall have a feature to send a heartbeat message to periodically notify users that they have communication with the system.

2.3 Operator Interface:

A. Install system software on the existing workstation at the client's existing location.

B. System Software:

1. Upgrade and otherwise modify existing system software to integrate new control sequences into existing system as described on drawings.

2.4 Controller Software:

A. Furnish the following applications software for building and energy management. All software applications shall reside and run in the system controllers and shall not be dependent upon any higher level computer or other controller for execution. Editing of applications shall occur at the operator interface.

1. Controllers shall have the ability to perform the following pre-tested control algorithms.

a. Two Position Control
b. Proportional Control
c. Proportional plus Integral Control
d. Proportional, Integral plus Derivative Control
e. Automatic Tuning of Control Loops
f. Model-Free Adaptive Control

2. Each controller shall be provided with an interactive HELP function to assist operators using portable devices and remote connected operators.

B. System Security

1. User access shall be secured using individual security passwords and user names.

2. Passwords shall restrict the user to only the objects, applications, and system functions as assigned by the system manager.

3. User logon/logoff attempts shall be recorded.

4. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user definable.

5. Use of workstation resident security as the only means of access control is not an acceptable alternative to resident system security at the field panel.

C. User Defined Control Applications

1. Controllers shall be able to execute custom user defined project-specific processes to automatically perform calculations and special control routines.

2. Any system measured point data or status, any system calculated data, a result from any process, or any user-defined constant in any controller in the system shall be available for use by any process.

3. Processes shall be able to command objects residing in any and all other controllers in the system.

4. Processes shall be able to generate operator messages at any operator interface, including being able to cause the execution of a dial-up connection to a remote device such as a pager or printer.

D. Scheduling:

1. Provide the capability to schedule each object or group of objects in the system. Schedules shall reside in the building controller and shall not rely on any external processing or network.

2. When a group of objects are scheduled together, provide the capability to define advances and delays for each member

3. There shall be provision for an authorized user to manually override each schedule.

4. Each schedule shall include the capability for start, stop, optimal start, optimal stop, and night economizer actions and shall consist of up to [**10**] events. Each schedule shall consist of the following:

a. Weekly Schedule: Provide separate schedules for each day of the week.

b. Exception Schedules: Provide the ability for the operator to designate any day of the year as an exception schedule. This exception schedule shall override the standard schedule for that day. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed it will be discarded and replaced by the standard schedule for that day of the week.

c. Holiday Schedules: Provide the capability for the operator to define up to **99** special or holiday schedules. These schedules may be placed on the scheduling calendar and will be repeated each year. The operator hall be able to define the length of each holiday period.

d. Optimal Start/Stop: The scheduling application outlined above shall support an optimal start/stop algorithm. This shall calculate the thermal characteristics of a zone and start the equipment prior to occupancy to achieve the desired space temperature at the specified occupancy time. The algorithm shall calculate separate sets of heating and cooling rates for zones that have been unoccupied for less then and greater than 24 hours. Provide the ability to modify the start/stop algorithm based on outdoor air temperature. Provide an early start limit in minutes to prevent the system from starting before an operator determined time limit.

E. System Coordination: Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.

F. Alarm Management:

1. Alarm management shall be provided to monitor and direct alarm information to operator devices. Each building controller shall perform distributed, independent alarm analysis, minimize network traffic and prevent alarms from being lost.

2. Conditional alarming shall allow generation based upon user defined multiple criteria.

3. An alarm "shelving" feature shall be provided at the operator interface to disable alarms during testing (i.e., Pull-the-Plug).

4. Binary Alarms: Each binary object shall be set to alarm based on the operator-specified state. Provide the capability to disable alarming when the associated equipment is turned off or is being serviced.

5. Analog Alarms: Each analog object shall have both high and low alarm limits and warning limits. Alarming must be able to be automatically and manually disabled.

6. Alarm Reporting: The operator shall be able to determine the action to be taken in the event of an alarm. Alarms shall be routed to the appropriate workstations based on time and other conditions. An alarm shall be able to start programs, be logged in the event log, printed, generate custom messages graphics.

a. In addition to the object's descriptor, time and date, the user shall be able to print, display or store up to a 200 character message describing the alarm condition or action to be taken.

b. Each controller shall be able to store at least fifty (50) alarm messages, each assignable to any number of objects in the controller.

c. Alarm shall be capable of initiating a call to a remote operator device.

G. Night Setback Control: Provide the ability to automatically adjust setpoints for night control.

H. Maintenance Management: The system shall monitor equipment status and generate maintenance messages based upon user designated run time, starts, and/or calendar date limits.

I. Sequencing: Provide application software based on the sequences of operation specified to properly sequence chillers, boilers, pumps, fans etc.

J. PID Control: A PID (proportional-integral-derivative) algorithm with direct or reverse action and anti-wind-up shall be supplied. The algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs. The controlled variable, set-point, and PID gains shall be user-selectable. The set-point shall optionally be chosen to be a reset schedule.

K. Staggered Start:

1. This application shall prevent all controlled equipment from simultaneously restarting after a power outage. The order in which equipment (or groups of equipment) is started; along with the time delay between starts shall be user-selectable.

2. Upon restoration of power, each building controller shall analyze the status of all controlled equipment, compare it with normal occupied mode of operation and enable/disable equipment as necessary to resume normal mode operation.

L. Calculations:

1. Provide software to allow instantaneous power (e.g. KW) or flow rates (e.g. L/s [**GPM**]) to be accumulated and converted to energy usage data.

2. Provide an algorithm that calculates a sliding-window average. The algorithm shall be flexible to allow window intervals to be user specified.

3. Provide an algorithm that calculates a fixed window average. A digital input signal will define the start of the window period to synchronize the fixed window average with that used by the utility.

4. Provide an algorithm that calculates energy usage and weather data (heating and cooling degree days). These items shall all be available for daily, previous day, monthly and the previous month.

M. Anti-Short Cycling: All binary output points shall be protected from short cycling. This feature shall allow minimum on-time and off-time to be selected.

N. On/Off Control with Differential: Provide an algorithm that allows a binary output to be cycled based on a controlled variable and set point. The algorithm shall be direct-acting or reverse-acting and incorporate an adjustable differential.

O. Totalization:

1. Run Time Totalization: Provide software to totalize run-times for all binary input and output objects. A high run-time alarm shall be assigned, if required, by the operator.

2. Consumption Totalization: Provide software to automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for all calculated, analog and digital input type objects.

3. Event Totalization: Provide software to count events such as number of motor starts. Totalization shall be performed on a daily, weekly, or monthly basis for all objects.

2.5 Advanced Application Controllers:

A. General: Provide Advanced Application Controllers to provide the performance specified in section 1 of this division. Each of these panels shall meet the following requirements.

1. Provide an AAC for control of each piece of equipment including but not limited to the following, except where controlled by a building controller.

a. Air Handling Units

2. Each AAC shall be capable of stand-alone operation and shall continue to provide control functions without being connected to the network.

3. Data shall be shared between networked AACs.

4. The operating system of the controller shall manage the input and output communication signals to allow distributed controllers to share real and virtual point information and allow central monitoring and alarms.

5. Controllers that perform scheduling shall have a real time clock.

6. The controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall:

a. Assume a predetermined failure mode.
b. Generate an alarm notification.

B. Communications:

1. The controller shall provide a minimum of one EIA 232C serial communication port for connection to a portable operator's terminal, printer or lap top computer.

C. Environment: Controller hardware shall be suitable for the anticipated ambient conditions.

1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for operation at -40°F to 150°F.

2. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 32°F to 120°F.

D. Keypad:

1. Provide a local keypad and display for each AAC. Operator shall be able to use keypad to view and edit data. Keypad and display shall require password to prevent unauthorized use.

2. If the manufacturer does not normally provide a keypad and display, provide the software and any interface cabling needed to use a laptop computer as a Portable Operator's Terminal for the system.

E. Serviceability: Provide diagnostic LEDs for power, communications, and processor. All wiring connections shall be made to field removable, modular terminal strips or to a termination card connected by a ribbon cable.

F. Memory:

4. The controller shall have sufficient memory (72 megabyte minimum) to support its operating system, database, and programming requirements.

5. In the event of power loss, there shall be an orderly shut down of all controllers to prevent the loss of database or operating system software.

6. Memory for critical controller configuration data shall be non-volatile type. Battery back-up shall be provided to maintain real-time clock and all volatile memory in the event of a power loss for at least 30 days

G. Immunity to Power and Noise: Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shut-down below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios of to 5 kW at 3 ft.

2.6 Application Specific Controllers:

A. General: Application specific controllers (ASC) are microprocessor-based DDC controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment. They are not fully user programmable, but are customized for operation within the confines of the equipment they are designed to serve.

1. Provide an ASC for control of each piece of equipment including but not limited to the following.

a. Variable Air Volume Terminal Boxes
b. Constant Air Volume Terminal Boxes
c. Fans

2. Each ASC shall be capable of stand-alone operation and shall continue to provide control functions without being connected to the network.

3. The use of ASCs to control air handling units etc. is not acceptable.

4. Control Algorithms: The controller shall receive its real-time data from the building controller time clock to insure sub-network continuity. Each controller shall include algorithms incorporating proportional, integral and derivative (PID) gains for all applications. All PID gains and biases shall be field-adjustable by the user via room sensor LCD or the portable operator's terminal as specified herein. Controllers that incorporate proportional and integral (PI) control algorithms only shall not be acceptable.

5. Control Applications: Operating programs shall be field-selectable for specific applications. In addition, specific applications may be modified to meet the user's exact control strategy requirements, allowing for additional system flexibility. Controllers that require factory changes of all applications are not acceptable.

6. Calibration: Each controller shall include provisions for manual and automatic calibration of the differential pressure transducer in order to maintain stable control and insure against drift over time.

   a. Manual calibration may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Calibration of the transducer at the controller location shall not be necessary

   b. Calibration shall be accomplished by stroking the terminal unit damper actuator to a 0% position so that a 0 CFM air volume reading is sensed. The controller shall automatically accomplish this whenever the system mode switches from occupied to unoccupied or vice versa.

   c. Calibration shall be accomplished by zeroing out the pressure sensor and holding damper at last known position until calibration is complete. The controller shall automatically accomplish this whenever the system mode switches from occupied to unoccupied or vice versa.

B. Communications:

1. Each controller shall perform its primary control function independent of other sub-network communication or if communication is interrupted

2. The controller shall provide a communications port for connection to a Portable Operators Terminal. This connection shall be extended to the space temperature sensor shown on the plans.

C. Environment: Controller hardware shall be suitable for the anticipated ambient conditions.

1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within waterproof enclosures and shall be rated for operation at -40°F to 150°F.

2. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 32°F to 120°F.

D. Serviceability: Provide diagnostic LEDs for power and communications. All wiring connections shall be made to field removable, modular terminal strips or to a termination card connected by a ribbon cable.

E. Memory:

1. Each ASC shall have sufficient memory to accommodate object databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM, EPROM and PROM. The controllers shall return to normal operation without operator intervention after a power failure of unlimited duration.

2. Upon replacement, new ASCs shall recover control function and site specific defaults automatically and resume normal operation.

F. Immunity to Power and noise: Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80%. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios of to 5 kW at 3 feet.

G. Power Supply:

1. The ASCs shall be powered from a 24 VAC source and shall function normally within an operating range of 18-24 VAC allowing for power source fluctuations.

2. Power supply for the ASC must be rated at minimum of 125% of ASC power consumption, and shall be fused or current limiting type.

3. The BAS contractor shall provide 24 VAC power to ASCs by utilizing one of the following

a. Existing line voltage power trunk with separate isolation transformers at each controller.

b. Dedicated line voltage power source and isolation transformers at central distribution location and a dedicated 24 VAC power line to multiple ASCs.

H. Space Temperature Sensors:

1. Each controller performing space temperature control shall be provided with a matching room temperature sensor.

2. Wired Sensor specifications. The sensor may be either RTD or thermistor type providing the following.

a.	Accuracy:	± 0.5ºF
b.	Operating Range:	35º to 115º F
c.	Set Point Adjustment Range:	55º to 95º F
d.	Calibration Adjustments:	None required
e.	Installation:	Up to 100 ft. from controller
f.	Auxiliary Communications Port:	as required
g.	Local LCD Temperature Display:	as required
h.	Set Point Adjustment Dial:	as required
i.	Occupancy Override Switch:	as required
j.	Color:	White

3. Set Point Modes:

   a. Independent Heating, Cooling
   b. Night Setback-Heating
   c. Night Setback-Cooling

4. Auxiliary Communication Port: Each room temperature sensor shall include a terminal jack integral to the sensor assembly. The terminal jack shall be used to connect a portable operator's terminal to control and monitor all hardware and software points associated with the controller. RS-232 communications port shall allow the operator to query and modify operating parameters of the local room terminal unit from the portable operator's terminal.

5. LCD Display: Interactive, two- line liquid crystal display shall allow the operator to query and modify operating parameters of the local room terminal unit from the room sensor. The display shall indicate the space temperature and associated ASC point when not being used to query or modify operating parameters.

6. Set Point Adjustment Dial: The set point adjustment dial shall allow for modification of the temperature by the building operators. Set point adjustment may be locked out, overridden, or limited as to time or temperature through software by an authorized operator at any central workstation, building controller, room sensor two-line display, or via the portable operator's terminal.

7. Override Switch: An override switch shall initiate override of the night setback mode to normal (day) operation when activated by the occupant and enabled by building operators. The override shall be limited to two (2) hours (adjustable.) The override function may be locked out, overridden, or limited through software by an authorized operator at the operator interface, building controller, room sensor two-line display or via the portable operator's terminal.

2.7 Input / Output Interface:

A. Hard-wired inputs and outputs may tie into the system through Building, Advanced, or Application Specific Controllers.

B. All input points and output points shall be protected such that shorting of the point to itself, another point, or ground will cause no damage to the controller. All input and output points shall be protected from voltage up to 24V of any duration, such that contact with this voltage will cause no damage to the controller.

C. Binary Inputs: Binary inputs shall allow the monitoring of on/off signals from remote devices. The binary inputs shall provide a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against the effects of contact bounce and noise. Binary inputs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.

D. Pulse Accumulation Inputs. This type of point shall conform to all the requirements of Binary Input points, and also accept up to 10 pulses per second for pulse accumulation.

E. Analog Inputs: Analog inputs shall allow the monitoring of low voltage (0-10 VDC), current (4-20 mA), or resistance signals (thermistor, RTD). Analog inputs shall be compatible with, and field configurable to commonly available sensing devices.

F. Binary Outputs: Binary outputs shall provide for on/off operation, or a pulsed low voltage signal for pulse width modulation control. Binary outputs on custom and building controllers shall have 3-position (on/off/auto) override switches and status lights. Outputs shall be selectable for either normally open or normally closed operation.

G. Analog Outputs: Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0-10 VDC or a 4-20 mA signal as required to provide proper control of the output device. Analog outputs on building or custom programmable controllers shall have status lights, a 2-position (auto/manual) switch, and manually adjustable potentiometer for manual override. Analog outputs shall not exhibit a drift of greater than 0.4% of range per year.

H. Tri-State Outputs: Provide tri-state outputs (two coordinated binary outputs) for control of three-point floating type electronic actuators without feedback. Use of three-point floating devices shall be limited to zone control and terminal unit control applications.

I. Universal Inputs and Outputs: Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

J. System Object Capacity: The system size shall be expandable to at least twice the number of input / output objects required for this project. Additional controllers (along with associated devices and wiring) shall be all that is necessary to achieve this capacity requirement. The operator interface installed for this project shall not require any hardware additions in order to expand the system.

2.8 Power Supplies and Line Filtering:

A. Power Supplies: Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.

    a. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.

    b. Line voltage units shall be UL recognized and CSA listed.

B. Power Line Filtering:

1. Isolation shall be provided at all network terminations, as well as all field point terminations to suppress induced voltage transients consistent with the following:

    a. RF-Conducted Immunity (RFCI) per ENV 50141 (IEC 1000-4-6) at 3V
    b. Electro Static Discharge (ESD) Immunity per EN 61000-4-2 (IEC 1000-4-2) at 8 kV air discharge, 4 kV contact
    c. Electrical Fast Transient (EFT) per EN 61000-4-4 (IEC 1000-4-4) at 500 V signal, 1 kV power
    d. Output Circuit Transients per UL 864 (2,400V, 10A, 1.2 Joule max)

2. All electric wiring that serves as power for the computer system, microprocessors, or other field panels shall have surge protective devices installed to suppress induced voltage transients consistent with IEEE standard 587-1980. Unit shall provide continuous non-interrupting protection with no degradation in protection capabilities. Instant automatic reset after safely eliminating transient surges from switching or other forms of transient over-voltages is required. Voltage clamping level shall be 120 percent of nominal line voltage.

3. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:
    a. Dielectric strength of 1000 V minimum
    b. Response time of 10 nanoseconds or less
    c. Transverse mode noise attenuation of 65 dB or greater
    d. Common mode noise attenuation of 150 dB or greater at 40-100 Hz

2.9 Auxiliary Control Devices:

A. Control Dampers:

1. Furnish and install a low leakage damper with opposed blade action. Linkage shall be concealed in frame. Finish shall be **mill galvanized**.

2. Frame: Frame shall be 5" x minimum 16 gage (127 x minimum 1.6 mm) roll formed, galvanized steel hat-shaped channel, reinforced at corners. Structurally equivalent to 13 gage (2.3 mm) U-channel.

3. Blades: Blades shall be airfoil shaped single-piece style with a nominal width of 6". Blade construction shall be minimum 14 gage equivalent thickness galvanized steel.

4. Axles: Minimum 1/2 inch (13 mm) diameter plated steel, hex-shaped, mechanically attached to blade.

5. Bearings: Self-lubricating stainless steel sleeve, turning in extruded hole in frame.

6. Seals: Blade edge seals shall be extruded vinyl type for ultra-low leakage from -76 to 350 degrees F (-60 to 177 degrees C). Blade seals shall be mechanically attached to blade edge and be field replaceable. Jamb seals shall be flexible metal compression type. Adhesive or clip-on blade types are not acceptable.

7. Approved Manufacturer: Ruskin CD60; or Approved equal.

2.10 Auxiliary Control Devices:

A. Damper Actuators:

1. The actuator shall be direct coupled over the shaft, enabling it to be mounted directly to the damper shaft without the need for connecting linkage. The fastening clamp assembly shall be of a "V" bolt design with associated "V" shaped toothed cradle attaching to the shaft for maximum strength and eliminating slippage. Spring return actuators shall have a "V" clamp assembly of sufficient size to be directly mounted to an integral jackshaft of up to 1.05 inches when the damper is constructed in this manner. Single bolt or set screw type fasteners are not acceptable.

2. The actuator shall have electronic overload or digital rotation sensing circuitry to prevent damage to the actuator throughout the rotation of the actuator. Mechanical end switches or magnetic clutch to deactivate the actuator at the end of rotation are not acceptable.

3. For power-failure/safety applications, an internal mechanical, spring return mechanism shall be built into the actuator housing. Non-mechanical forms of fail-safe operation are not acceptable.

4. All spring return actuators shall be capable of both clockwise and counterclockwise spring return operation by simply changing the mounting orientation.

5. Proportional actuators shall accept a 0 to 10 VDC or 0 to 20 mA control signal and provide a 2 to 10 VDC or 4 to 20 mA operating range. An actuator capable of accepting a pulse width modulating control signal and providing full proportional operation of the damper is acceptable. All actuators shall provide a 2 to 10 VDC position feedback signal.

6. All 24 VAC/VDC actuators shall operate on Class 2 wiring and shall not require more than 10 VA for AC or more than 8 watts for DC applications. Actuators operating on 120 VAC power shall not require more than 10 VA. Actuators operating on 230 VAC power shall not require more than 11 VA.

7. All non-spring return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring return actuators with more than 60 in-lb torque capacity shall have a manual crank for this purpose.

8. All proportional actuators shall have an external, built-in switch to allow the reversing of direction of rotation.

9. Actuators shall be provided with a conduit fitting and a minimum three-foot electrical cable and shall be pre-wired to eliminate the necessity of opening the actuator housing to make electrical connections.

10. Actuators shall be designed for a minimum of 60,000 full stroke cycles at the actuator's rated torque.

11. The actuator shall have a 5-year warranty.

12. Approved Manufacturers: BELIMO.

B. Control Valves:

1. Pressure Independent Actuated Ball Valves:

a. Provide for Chilled Water and Heating Hot Water systems for valves ½" through 2" in size.

b. The modulating control valves shall be pressure independent and shall include a Self-Balancing Cartridge and Actuated Ball Valve in a single

valve housing. Valve housing shall consist of forged brass, rated at no less than 360 psi at 250°F. Valve shall have a fixed end or union end connection.

c. The control valve shall accurately control the flow from 0 to 100% full rated flow. A flow tag shall be furnished with each valve.

d. Self-Balancing Cartridge (SBC):

1) SBC shall automatically control flow rates with +/-5% accuracy over an operating range at least 10 times the minimum required for control.
2) The operating pressure range shall be available with the minimum range requiring less than 5.8 PSID to actuate the mechanism.
3) Valve internal control mechanism shall include a diaphragm and full travel linear coil spring.
4) Valves shall include an accessible/ replaceable cartridge.

e. Actuated Ball Valve:

1) Ball valve shall consist of chemically plated nickel brass or stainless steel.
2) Actuator stem shall be removable/replaceable without removing valve from line.
3) Manufacturer shall be able to provide ball insert to make flow control equal percentage.
4) Valve shall have EPDM O-rings behind the seals to allow for a minimum close-off pressure of 100 psi with 35 in-lbs of torque for 1/2" – 2" sizes.
5) Actuator shall provide minimum torque required for full valve shutoff position.

f. Approved Manufacturers: Belimo, PICCV; Griswold Controls, PIOCV or MVP; Flow Control Industries, DeltaPValve.

2. Valve Selection:

a. Pressure Independent Control Valves: Select valve based on design coil flow and pressure differential range.

3. Valve Actuators:

a. Actuators used near outdoor air streams shall have NEMA type 2 (IP54) housings for water and moisture resistance.

b. Actuators shall be applied according to the manufacturer's specifications.

c. The valve actuator shall be capable of providing the minimum torque required for proper valve close-off for the required application.

d. Each actuator shall have current limiting circuitry or microprocessor overload protection incorporated in its design to prevent damage to the actuator.

e. Actuator shall have manual override equipped with interlocking device to protect actuator from over-torque of manual override.

f. Applications that require fail safe operation of the valve assembly shall use actuators with mechanical spring return.

g. The actuator shall be proportional, floating (Tri-state), or two position with spring return as called out in the control sequence of operation. All proportional valves shall be positive positioning, and respond to a 2-10 VDC or 4-20 mA with a load resistor. These proportional units will each have position feedback signal corresponding to the actual valve position which can be wired back to the control system.

h. All control valves shall have a visual position indicator and an attached 3 foot cable for easy installation to a junction box.

4. Approved Manufacturers: BELIMO; Griswold Controls; Flow Control Industries

C. Binary Temperature Devices:

1. Low-Limit Thermostats: Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 20 ft long. Element shall sense temperature in each 1 ft section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

D. Temperature Sensors: Temperature sensors shall be Platinum Resistance Temperature Device (RTD) with the following characteristics.

1. Room Temperature:

a.	Temperature monitoring range	+40/+90º F (+40/120ºF for high temp alarms)
b.	Output signal	4-20 mA
c.	Installation adjustments	none required
d.	Calibration adjustments	zero & span
e.	Factory calibration point	70º F
f.	Accuracy at calibration point	±0.5º F

2. Liquid Immersion Temperature

a.	Temperature monitoring range	+20/+120º F or +70/+220º F
b.	Output signal	4-20 mA
c.	Installation adjustment	none required
d.	Calibration adjustments	zero & span
e.	Factory calibration point	70º F
f.	Accuracy at calibration point	±0.5º F

3. Duct (Single Point) Temperature

a.	Temperature monitoring range	+20/+120º F
b.	Output signal	4-20 mA
c.	Installation adjustments	none required
d.	Calibration adjustments	zero & span
e.	Factory calibration point	70º F
f.	Accuracy at calibration point	±0.5º F

4. Duct (Averaging) Temperature

a.	Temperature monitoring range	+20/+120º F
b.	Output signal	4 - 20 mA
c.	Installation adjustments	none required
d.	Calibration adjustments	zero & span
e.	Factory calibration point	70º F
f.	Accuracy at calibration point	±0.5º F

5. Outside Air Temperature

a.	Temperature monitoring range	-50/+122º F
b.	Output signal	4-20 mA
c.	Installation adjustments	none required
d.	Calibration adjustments	zero & span
e.	Factory calibration point	70º F
f.	Accuracy at calibration point	±0.5º F

6. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 5 ft in length per 10 ft^2 of duct cross section.

7. Immersion sensors shall be provided with a separable stainless steel well. Pressure rating of well is to be consistent with the system pressure in which it is to be installed. The well must withstand the flow velocities in the pipe.

8. Space sensors shall be equipped with set point adjustment, override switch, digital display, and communications port.

9. Provide matched temperature sensors for differential temperature measurement. Differential accuracy shall be within 0.2 F.

10. Approved Manufacturer: Siemens, Vaisala

E. Dewpoint / Humidity Sensors:

1. Outside Air Dew Point Temperature

a.	Dew point monitoring range	-40º/+115º F DP, 12% to 99% RH
b.	Output signal	4-20 mA
c.	Calibration adjustments	zero & span
d.	Factory calibration point	70º F

e.	Accuracy at calibration point	±2.0º Fdp

2. Room / Duct Relative Humidity

a.	Sensor Humidity range	0 to 100%
b.	Operating temperature	15º F to 170º F
c.	Accuracy	±2% RH
d.	Sensing element	Capacitive sensor
e.	Output signal	4-20 mA DC
f.	Installation adjustments	zero & span
g.	Operating temperature	15º F to 170º F
h.	Voltage requirement	12-36 VDC

3. Humidity sensors shall not drift more than 1% of full scale annually.

4. Approved Manufacturer: Siemens, Vaisala

F. Relays:

1. Control Relays: Control relays shall be UL listed, and shall have dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage shall be suitable for application.

2. Time Delay Relays: Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable ±100% from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

G. Current Switches:

1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. Select switches to match application current and DDC system output requirements.

2. Current switches shall be tested to provide positive indication of belt failure.

H. Air Pressure Sensor: Provide loop powered static, velocity and differential pressure sensor with following characteristics.

1.	Range:	per application
2.	Accuracy:	± 0.05” w.g.
3.	Output Signal:	4-20 mA
4.	Combined Static Error:	0.5% full range
5.	Operating Temperature:	-40º / 175ºF
6.	LCD display:	Yes
7.	Approved Manufacturer:	Setra Model #2671005WD11A1HD

I. Differential Pressure Switches:

1. Water Differential Pressure Switch: Differential pressure switches shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum) and shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified. Provide switch with mechanical analog indicator. The differential switch shall have the following characteristics.

a.	Range:	8 to 70 psi
b.	Differential:	3 psi
c.	Maximum Differential Pressure:	200 psi
d.	Maximum Pressure:	325 psig
e.	Approved Manufacturer:	Dresser Model# 35-1132AS-25S-XV4

2. Air Differential Pressure Switch: Differential pressure switches shall be diaphragm type, with die-cast aluminum housing and adjustable set point. Switch rating shall be a minimum 5 amps at 120 VAC. Switch shall be SPDT with a pressure range suited for application.

J. Indoor Air Quality (CO_2 / VOC) Sensors: Provide indoor air quality sensors to monitor Carbon Dioxide (CO_2) and Volatile Organic Compound (VOC) levels. The sensors shall be microprocessor-based photoacoustic type with heated stannic dioxide semiconductor. Provide sensors with following characteristics:

1.	Operating voltage:	24 VAC ±20%
2.	Frequency:	50/60 Hz
3.	Power consumption:	max. 6 VA
4.	CO_2 measuring range:	0 – 2000 ppm
5.	Tolerance:	± 100 ppm
6.	Output:	0 – 10 VDC
7.	Calibration:	none required
8.	VOC measurement range:	0 – 10 V_{VOC}
9.	Permissible air velocity in duct:	< 26.2 Ft/s.

10. The CO_2 sensors shall have no more than 1% drift during the first year of operation and minimal drift thereafter so that no calibration will be required.
11. The VOC sensor shall have automatic self calibrating capability to ensure accuracy.
12. Sensors shall be wall or duct mounted type as indicated on plans and/or in the sequence of operation.

    a. Wall mounted sensors shall be provided with white plastic cover, without LED indicators.

    b. Duct mounted sensors shall be provided with LED indicators in a dust proof plastic housing with transparent cover.

13. Approved Manufacturer: Siemens QP*** Series

K. Air Flow Measuring Stations:

1. Thermistor Type (All Applications Except VVTs):

a. Airflow and temperature measurement: Thermal anemometer using instrument grade self heated thermistor sensors with thermistor temperature sensors. Flow measurement drift shall not exceed manufacturer's repeatability statement for the life of the equipment.

b. Construction: Provide one glass encapsulated self heated thermistor and one glass encapsulated thermistor temperature sensor for each sensing point. Support struts and brackets shall be tubular aluminum extrusion.

c. Electronics: Microprocessor based; solid state in aluminum enclosure. Use NEMA 4 enclosure for exterior installation. Provide transmitter with 4-20 mA analog output signals.

d. Approved Manufacturers: Ebtron, Gold Series (duct & plenum installations), Silver Series (fan inlet).

2. Velocity Pressure Type (Variable Volume Terminals):

a. Pressure sensors shall withstand up to 150 percent of rated pressure. Pressure sensor accuracy shall be plus or minus one percent of full scale. Pressure sensors shall be capsule, diaphragm, bellows, bourdon tube, or solid state.

b. Multi-point, multi-axis flow ring or cross sensor to be furnished. Single point or flow bar sensors are not acceptable. Shall be capable of maintaining airflow to within +/- 5 percent of rated unit airflow setpoint with 1.5 duct diameters straight duct upstream from the unit.

S. Local Control Panels:

1. Indoor control panels shall be fully enclosed NEMA 1 construction with hinged door key-lock latch and removable sub-panels. A common key shall open each control panel and sub-panel.

2. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals shall be UL listed for 600 V service, individually identified per control and interlock drawings, with adequate clearance for field wiring.

3. Each local panel shall have a control power source power switch (on-off) with overcurrent protection.

2.11 Wiring And Raceways:

A. General: Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.

B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

C. Intra-building conductors (cables) shall utilize fiber optic conductors.

2.12 Fiber Optic Cable System:

A. Optical Cable: Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. Sheath shall be UL listed OFNP in accordance with NEC Article 770. Optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125mm. Cable installed outdoors or underground shall be gel coated and rated for such installation.

1. Provide minimum of four (4) strands for each run including two (2) spares.
2. 1 GB Ethernet networks shall be single mode fiber, with two (2) strands of µm cable, for lengths exceeding 275 meters.

B. Connectors: Field terminate optical fibers with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.

3.0 EXECUTION:

3.1 Examination:

A. The project plans shall be thoroughly examined for control device and equipment locations, and any discrepancies, conflicts, or omissions shall be reported to the Architect/Engineer for resolution before rough-in work is started.

B. The contractor shall inspect the site to verify that equipment is installable as shown, and any discrepancies, conflicts, or omissions shall be reported to the Architect/Engineer for resolution before rough-in work is started.

C. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies to Engineer and obtain written instructions for changes necessary to accommodate Section 230910 work with work of others. Controls Contractor shall perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.2 Protection:

A. Controls Contractor shall protect against and be liable for damage to work and to material caused by Contractor's work or employees.

B. Controls Contractor shall be responsible for work and equipment until inspected, tested, and accepted. Protect material not immediately installed. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 Coordination

A. Site

1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other trades. If

installation without coordination causes interference with work of other trades, Contractor shall correct conditions without extra charge.

2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

B. Test and Balance:

1. Provide Test and Balance Contractor a single set of necessary tools to interface to control system for testing and balancing.

2. Train Test and Balance Contractor to use control system interface tools.

3. Provide a qualified technician to assist with testing and balancing
4. Test and Balance Contractor shall return tools undamaged and in working condition at completion of testing and balancing.

5. Test and Balance Contractor shall return all commanded control points that are not a permanent setting or coefficients to a normal state at the end of each workday and shall advise BAS contractor of planned activities prior to visiting jobsite.

6. Test and Balance Contractor shall provide BAS Contractor with a copy of all field reports and one (1) copy of the final TAB report which shall include all setting and coefficients made during TAB.

7. Test and Balance Contractor shall notify Central Utilities prior to any testing that uses campus chilled water or steam.

C. Life Safety:

1. Duct smoke detectors required for air handler shutdown are provided under Division 26. Interlock smoke detectors to air handlers for shutdown as specified in Section 230910 Appendix A (Sequences of Operation).

D. Coordination with Other Controls: Integrate with and coordinate controls and control devices furnished or installed by others as follows.

1. Communication media and equipment shall be provided as specified in Section 230910 Article 2.2 (Communication).

2. Each supplier of a controls product shall configure, program, start up, and test that product to meet the sequences of operation described in Section 230910 Appendix A regardless of where within the contract documents those products are described.

3. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.

4. Controls Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.

3.4 General Workmanship:

A. Install equipment, piping, wiring/conduit parallel to building lines (i.e. horizontal, vertical, and parallel to walls) wherever possible.

B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.

C. Install all equipment in readily accessible location as defined by Chapter 1, Article 100, Part A of the NEC. Control panels shall be attached to structural walls unless mounted in equipment enclosure specifically designed for that purpose. Panels shall be mounted to allow for unobstructed access for service.

D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.

E. All equipment, installation, and wiring shall comply with acceptable industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

3.5 Wiring:

A. Provide all electrical work required as an integral part of the digital control work. Install a complete wiring system for the control system including wire and miscellaneous materials as required for mounting and connecting control devices.

B. Electrical control and power wiring, contactors and relays required for BAS equipment, damper and valve actuators, and local control panels, not specifically identified in the Division 26 sections as electrical work or shown on the electrical drawings, is work of this section. Comply with the applicable requirements of Division 26 for the installation of electrical wiring incidental to the BAS system. If additional circuits need to be designated for this equipment, the control contractor shall include the cost to add these circuits.

C. Control panels serving equipment fed by emergency power shall also be served by emergency power. Equipment fed by emergency power is so indicated on mechanical equipment schedules and electrical plans.

D. Control and interlock wiring and installation shall comply with national and local electrical codes, Division 26 , and manufacturer's recommendations. Where the requirements of this section differ from Division 26, requirements of this section shall take precedence.

E. Color code each junction box cover plate indicating type with ½" self-adhesive colored dot or enamel spray paint with following color scheme.

1.	Low voltage wiring	green
2.	Pneumatic tubing	blue

3. Line voltage signal wiring yellow

F. NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway as specified by NEC and Division 26 requirements.

G. Low-voltage wiring shall meet NEC Class 2 requirements. Sub fuse low-voltage power circuits as required to meet Class 2 current limit.

H. NEC Class 2 (current-limited) wires not in raceway but in concealed and accessible locations such as return air plenums shall be UL listed for the intended application. Run exposed Class 2 wiring parallel to a surface or perpendicular to it and tie neatly at 3 m (10 ft) intervals. Use structural members to support or anchor plenum cables without raceway. Do not use ductwork, electrical raceways, piping, or ceiling suspension systems to support or anchor cables.

I. All wiring in mechanical, electrical or service rooms (or where subject to mechanical damage) shall be installed in raceway.

J. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).

K. Do not install wiring in raceway containing tubing.

L. Secure raceways with raceway clamps fastened to structure and spaced according to code requirements. Raceways and pull boxes shall not be hung on or attached to ductwork, electrical raceways, piping, or ceiling suspension systems.

M. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.

N. Size raceway and select wire size and type in accordance with manufacturer's recommendations and NEC requirements.

O. Include one pull string in each raceway 1 in. or larger.

P. Use color-coded conductors throughout.

Q. Locate control and status relays in designated enclosures only. Do not install control and status relays in packaged equipment control panel enclosures containing Class 1 starters.

R. Conceal raceways except within mechanical, electrical, or service rooms. Maintain minimum clearance of 6 in. between raceway and high-temperature equipment such as steam pipes or flues.

S. Adhere to requirements in Division 26 where raceway crosses building expansion joints.

T. Install insulated bushings on raceway ends and enclosure openings. Seal top ends of vertical raceways.

U. Terminate control and interlock wiring related to the work of this section. Maintain at the job site updated (as-built) wiring diagrams that identify terminations. Tag each wire termination at control panels, junction boxes, and remote control devices with unique ID number.

V. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 3 ft in length and shall be supported at each end. Do not use flexible metal raceway less than ½ in. electrical trade size. Use liquid-tight flexible metal raceways in areas exposed to moisture including chiller and boiler rooms.

W. Install raceway rigidly, support adequately, ream at both ends, and leave clean and free of obstructions. Join raceway sections with couplings and according to code. Make terminations in boxes with fittings. Make terminations not in boxes with bushings.

3.6 Communication Wiring

A. Communication wiring shall be low-voltage Class 2 wiring and shall comply with Article "Wiring" in Part 3 of this specification.
B. Primary building level network shall be minimum CAT 5 Ethernet cable. Secondary sub-network wiring shall be 24 gage, TSP low capacitance cable
C. Install communication wiring in separate raceways and enclosures from other Class 2 wiring.
D. During installation do not exceed maximum cable pulling, tension, or bend radius specified by the cable manufacturer.
E. Verify entire network's integrity following cable installation using appropriate tests for each cable.
F. Install lightning arrestor according to manufacturer's recommendations between cable and ground where a cable enters or exits a building.
G. Each run of communication wiring shall be a continuous length without splices when that length is commercially available. Runs longer than commercially available lengths shall have as few splices as possible using commercially available lengths.
H. Label communication wiring to indicate origination and destination.
I. Ground coaxial cable according to NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

3.7 Fiber Optic Cable:

A. During installation do not exceed maximum pulling tensions specified by cable manufacturer. Post-installation residual cable tension shall be within cable manufacturer's specifications.
B. Install cabling and associated components according to manufacturers' instructions. Do not exceed minimum cable and unjacketed fiber bend radii specified by cable manufacturer.

3.8 Installation of Sensors:

A. Install sensors according to manufacturer's recommendations.

B. Sensors shall be readily accessible and installed in such a manner as to allow for easy replacement. Temperature sensors must be installed in a manner that prevents condensation from making direct contact with the sensor's electronic components.

C. Mount sensors rigidly and adequately for operating environment.

D. Install space sensors on concealed junction boxes properly supported by wall framing. Mount space sensors 5'-0" AFF whenever possible or as shown on the drawings. Prior to installation coordinate and adjust the final device location with all casework, shelving, furniture, bulletin boards or other wall mounted furnishings.

E. Air seal wires attached to sensors in their raceways or in the wall to prevent sensor readings from being affected by air transmitted from other areas.

F. Use averaging sensors in mixing plenums and hot and cold decks. Install averaging sensors in a serpentine manner vertically across duct. Support each bend with a capillary clip.

G. Install mixing plenum low-limit sensors in a serpentine manner horizontally across duct. Support each bend with a capillary clip. Provide 1 ft of sensing element for each 1 ft^2 of coil area.

H. Install pipe-mounted temperature sensors in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.

I. Install outdoor air temperature sensors on north wall at designated location with sun shield.

J. Differential Air Static Pressure:

1. Supply Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.

K. Piping to pressure transducer pressure ports shall contain a capped test port adjacent to transducer.

L. Pressure transducers, except those controlling VAV boxes, shall be located in control panels, not on monitored equipment or on ductwork. Mount transducers in a vibration-free location accessible for service without use of ladders or special equipment.

M. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before tee for water gauges.

3.9 Safeties:

Smoke detectors, freezestats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation and shall not rely on the BAS to operate. Switches shall require manual reset. Interlock wiring shall be run in separate conduits from BAS associated wiring. Provide contacts that allow DDC software to monitor safety switch status.

3.10 Flow Switch Installation:

Use correct paddle for pipe diameter. Adjust flow switch according to manufacturer's instructions.

3.11 Warning Labels:

A. Affix permanent warning labels to equipment that can be automatically started by the control system.

1. Labels shall use white lettering (12-point type or larger) on a red background.
2. Warning labels shall read as follows.

C A U T I O N
This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to "Off" position before servicing.

B. Affix permanent warning labels to motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.
   1. Labels shall use white lettering (12-point type or larger) on a red background.
   2. Warning labels shall read as follows.

C A U T I O N
This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.

3.12 Identification of Hardware and Wiring:

A. Label wiring and cabling, including that within factory-fabricated panels, with control system address or termination number at each end within 2 in. of termination.

B. Label pneumatic tubing at each end within 2 in. of termination with a descriptive identifier.

C. Permanently label or code each point of field terminal strips to show instrument or item served.

D. Label control panels with minimum ½ in. letters on laminated plastic nameplates.

E. Label each control component with a permanent label. Label plug-in components such that label remains stationary during component replacement.

F. Label room sensors related to terminal boxes or valves with nameplates.

G. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

H. Label identifiers shall match record documents.

3.13 Controllers:

A. Provide a separate Controller for each major piece of HVAC equipment. Controller shall be located within the same room as equipment. All points associated with a single piece of equipment shall reside in a single controller. Points used for control loop reset such as outside air or space temperature are exempt from this requirement.

B. All controllers for variable volume terminal equipment shall be routed through the controller for the air handling unit associated with the terminal units.

C. Motors in motor control centers shall be controlled from the DDC controller associated with HVAC system. It shall not be acceptable to control all motors in a MCC from one DDC controller dedicated to the MCC. The intent of this

specification is that the loss of any one DDC controller shall not affect the operation of other HVAC systems, only for the points connected to the DDC controller.

3.14 Local Area Networks:

A. These following requirements are specific to the integration of multiple BACnet networks, possibly on different LAN types, into a single BACnet internetwork.

B. Network Numbering:

1. The naming convention shall be reviewed and coordinated with the owner, commissioning agent and engineer prior to implementation.

2. BACnet network numbers shall be based on a "facility code, network" concept. The "facility code" is an owner assigned numeric value assigned to a specific facility or building. The "network" typically corresponds to a "floor" or other logical configuration within the building. BACnet allows 65535 network numbers per BACnet internetwork.

3. Network numbers are thus formed as follows: Network Number = "FFFFN" where:
   FFFF = Facility Code
   N = 0-9 Allows up to 10 networks per facility or building.
   N = 0 will generally be assigned to the Building Level Network. Normally, this network is connected to the owner's management level network. The additional N-numbers will be assigned to any MS/TP networks as required.

C. IP Address Assignments: The Contractor shall contact the owner's IT department for assignment of IP addresses prior to beginning device configuration.

3.15 Programming:

A. Software Programming:

1. Provide programming for the system as per specifications and adhere to the sequence of operations provided. All other system programming necessary for the operation of the system but not specified in this document shall also be provided by the Control System Contractor. Imbed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequence of operations.

B. Operators' Interface:

1. Standard Graphics: Provide graphics for each major piece of equipment and floor plan in the building. This includes each Air Handler, VAV Terminal, .

These standard graphics shall show all points dynamically as specified in the points list.

2. The controls contractor shall provide all the labor necessary to install, initialize, start-up, and trouble-shoot all operator interface software and their functions as described in this section. This includes any operating system software, the operator interface data base, and any third party software installation and integration required for successful operation of the operator interface.

3.16 Control System Checkout and Testing:

A. Startup Testing: Complete startup testing to verify operational control system before notifying Owner of system demonstration. Provide Owner with schedule for startup testing. Owner may have representative present during any or all startup testing.

B. Calibrate and prepare for service each instrument, control, and accessory equipment furnished under Section 230910.

C. Verify that control wiring is properly connected and free of shorts and ground faults. Verify that terminations are tight.

D. Enable control systems and verify each input device's calibration. Calibrate each device according to manufacturer's recommendations.

E. Verify that binary output devices such as relays, solenoid valves, two-position actuators and control valves, and magnetic starters, operate properly and that normal positions are correct.

F. Verify that analog output devices such as I/Ps and actuators are functional, that start and span are correct, and that direction and normal positions are correct. Check control valves and automatic dampers to ensure proper action and closure. Make necessary adjustments to valve stem and damper blade travel.

G. Prepare a log documenting startup testing of each input and output device, with technician's initials certifying each device has been tested and calibrated.

H. Verify that system operates according to sequences of operation. Simulate and observe each operational mode by overriding and varying inputs and schedules. Tune PID loops and each control routine that requires tuning.

I. Alarms and Interlocks:
   1. Check each alarm with an appropriate signal at a value that will trip the alarm.
   2. Trip interlocks using field contacts to check logic and to ensure that actuators fail in the proper direction.
   3. Test interlock actions by simulating alarm conditions to check initiating value of variable and interlock action.

3.17 Control System Verification, Demonstration, and Acceptance:

A. Verification: Prior to demonstration, provide the following items to the Engineer.
   1. Provide screen prints of each graphic screen in 8 ½ " x 11" format.
   2. Provide programming logic in 8 ½" x 11" format. Programming logic shall include inline comments demonstrating compliance with sequence of operation.
   3. Provide remote login capabilities with temporary administrative privileges for engineer use during Verification, Demonstration, and Acceptance phase.

B. Demonstration: Prior to acceptance, perform the following performance tests to demonstrate system operation and compliance with specification after and in addition to

tests specified in Article “Control System Checkout and Testing” in Part 3 of this specification. Provide Engineer with log documenting completion of startup tests.

1. Engineer will be present to observe and review system demonstration. Notify Engineer at least 10 days before system demonstration begins.
2. Demonstration shall follow process submitted and approved under Section 230910 Article “Submittals”. Complete approved checklists and forms for each system as part of system demonstration.
3. Demonstrate actual field operation of each sequence of operation as specified. Provide at least two persons equipped with two-way communication. Demonstrate calibration and response of any input and output points requested by Engineer. Provide and operate test equipment required to prove proper system operation.
4. Demonstrate compliance with Article “System Performance”.
5. Demonstrate compliance with sequences of operation through each operational mode.
6. Demonstrate complete operation of operator interface.
7. Demonstrate each of the following.
    a. DDC loop response. Supply graphical trend data output showing each DDC loop's response to a setpoint change representing an actuator position change of at least 25% of full range. Trend sampling rate shall be from 10 seconds to 3 minutes, depending on loop speed. Each sample's trend data shall show setpoint, actuator position, and controlled variable values. Engineer will require further tuning of each loop that displays unreasonably under- or over-damped control.
    b. Building fire alarm system interface.
    c. Trend logs for each system. Trend data shall indicate setpoints, operating points, valve positions, and other data as specified in the points list provided with each sequence of operation in Section 230910 Appendix A. Each log shall cover three 48-hour periods and shall have a sample frequency not less than 10 minutes or as specified on its points list. Logs shall be accessible through system's operator interface and shall be retrievable for use in other software programs as specified.
8. Tests that fail to demonstrate proper system operation shall be repeated after Contractor makes necessary repairs or revisions to hardware or software to successfully complete each test.

C. Acceptance:

1. After tests described in this specification are performed to the satisfaction of both Engineer and Owner, Engineer will accept control system as meeting completion requirements. Engineer may exempt tests from completion requirements that cannot be performed due to circumstances beyond Contractor's control. Engineer will provide written statement of each exempted test. Exempted tests shall be performed as part of warranty.
2. System shall not be accepted until completed demonstration forms and checklists are submitted and approved as required in Section 230910 Article “Submittals”.

3.18 Cleaning:

A. Each day clean up debris resulting from work. Remove packaging material as soon as its contents have been removed. Collect waste and place in designated location.
B. On completion of work in each area, clean work debris and equipment. Keep areas free from dust, dirt, and debris.
C. On completion of work, check equipment furnished under this section for paint damage. Repair damaged factory-finished paint to match adjacent areas. Replace deformed cabinets and enclosures with new material and repaint to match adjacent areas.

3.19 Training:

A. Provide training for a designated staff of Owner's representatives. Training shall be provided via self-paced training, web-based or computer-based training, classroom training, or a combination of training methods.
    1. Provide minimum of four (4) hours of on-site training after system start-up and acceptance by owner and engineer.
    2. Provide minimum of four (4) additional hours of on site training 6-12 months after initial training is completed.
    3. Schedule training sessions with owner.
B. Training shall enable students to accomplish the following objectives.
    1. Proficiently operate system
    2. Understand control system architecture and configuration
    3. Understand DDC system components
    4. Understand system operation, including DDC system control and optimizing routines (algorithms)
    5. Operate workstation and peripherals
    6. Log on and off system
    7. Access graphics, point reports, and logs
    8. Adjust and change system setpoints, time schedules, and holiday schedules
    9. Recognize common HVAC system malfunctions by observing system graphics, trend graphs, and other system tools
    10. Understand system drawings and Operation and Maintenance manual
    11. Understand job layout and location of control components
    12. Access data from DDC controllers
    13. Operate portable operator's terminals
    14. Create and change system graphics
    15. Create, delete, and modify alarms, including configuring alarm reactions
    16. Create, delete, and modify point trend logs (graphs) and multi-point trend graphs
    17. Configure and run reports
    18. Add, remove, and modify system's physical points
    19. Create, modify, and delete application programming
    20. Add operator interface stations
    21. Add a new controller to system
    22. Download firmware and advanced applications programming to a controller
    23. Configure and calibrate I/O points
    24. Maintain software and prepare backups
    25. Interface with job-specific, third-party operator software
    26. Add new users and understand password security procedures

C. Provide course outline and materials according to Section 230910 Article 1.10 (Submittals). Provide one copy of training material per student.

D. Instructors shall be factory-trained and experienced in presenting this material.

4.0 SEQUENCES OF OPERATION / POINT (OBJECT) LISTS

4.1 Sequences of Operation

A. All user adjustable / selectable points or objects described on the drawings shall be available to the user via dynamic graphics or text based interface (see object / point list) at the operator workstation without requiring the user to edit the application program.

B. User adjustable time delays and deadbands are not specifically shown in object / point lists, but shall be available to the user via dynamic graphics or text based interface at the operator workstation without requiring the user to edit the application program.

C. See drawings for Sequences of Operation and Point (Object) Lists.

END OF SECTION

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SECTION 232113 - HYDRONIC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. This Section includes pipe and fitting materials, joining methods, special-duty valves, and specialties for the following:

1. Hot-water heating piping.
2. Chilled-water piping.
3. Condensate-drain piping.
4. Air-vent piping.

B. Related Sections include the following:

1. Division 23 Section "Hydronic Pumps" for accessories for hydronic piping.

1.3 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature:

1. Hot-Water Heating Piping: 150 **psig (kPa** at **200 deg F (93 deg C**.
2. Chilled-Water Piping: 150 **psig (kPa** at **200 deg F (93 deg C**.
3. Makeup-Water Piping: 125 **psig (552 kPa** at **150 deg F (66 deg** C.
4. Condensate-Drain Piping: **150 deg F (66 deg** C.
5. Air-Vent Piping: **200 deg F (93 deg C**.

1.4 SUBMITTALS

A. Product Data: For each type of the following:
1. Valves. Include flow and pressure drop curves based on manufacturer's testing for balancing valves and automatic flow-control valves.
2. Air control devices.
3. Hydronic specialties.

B. Welding certificates.

A. Coordinate firstQualification Data: For Installer.

C. Operation and Maintenance Data: For air control devices, hydronic specialties, and special-duty valves to include in emergency, operation, and maintenance manuals.

D. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

1.5 QUALITY ASSURANCE

A. Steel Support Welding: Qualify processes and operators according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

B. Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Comply with provisions in ASME B31 Series, "Code for Pressure Piping."
2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

C. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 01.

PART 2 - PRODUCTS

2.1 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: **ASTM B 88, Type L (ASTM B 88M, Type B**.

B. Annealed-Temper Copper Tubing: ASTM B 88, Type K (ASTM B 88M, Type A).

C. DWV Copper Tubing: ASTM B 306, Type DWV.

D. Wrought-Copper Fittings: ASME B16.22.

E. Wrought-Copper Unions: ASME B16.22.

2.2 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; type, grade, and wall thickness as indicated in Part3 "Piping Applications" Article.

B. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in Part 3 "Piping Applications" Article.

C. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in Part 3 "Piping Applications" Article.

D. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

E. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

1. Material Group: 1.1.
2. End Connections: Butt welding.
3. Facings: Raised face.

F. Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.

2.3 JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch (3.2-mm) maximum thickness unless thickness or specific material is indicated.

a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

C. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

D. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

E. Retain twoGasket Material: Thickness, material, and type suitable for fluid to be handled and working temperatures and pressures.

1.2 DIELECTRIC FITTINGS

A. Description: Combination fitting of copper-alloy and ferrous materials with threaded, solder-joint, plain, or weld-neck end connections that match piping system materials.

B. Insulating Material: Suitable for system fluid, pressure, and temperature.

C. Dielectric Unions:

1. Factory-fabricated union assembly, for 250-psig 1725-kPa minimum working pressure at 180 deg F 82 deg C.

D. Dielectric-Flange Kits:

1. Companion-flange assembly for field assembly. Include flanges, full-face- or ring-type neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and

steel backing washers.

2. Separate companion flanges and steel bolts and nuts shall have 150- or 300-psig 1035- or 2070-kPa minimum working pressure where required to suit system pressures.

2.4 VALVES

A. Gate, Ball, and Butterfly Valves: Comply with requirements specified in Division 23 Section "General-Duty Valves for HVAC Piping."

B. Automatic Flow Control Valve:

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

   a. Flow Design Inc.
   b. Griswold Controls.

3. Body:

   a. NPS 2 1/2" to 3": Ductile iron.
   b. NPS 3" and Larger: Gray iron.

4. Connections:

   a. NPS 2 1/2" to 3": Flanged.

2. NPS 3" and Larger: Wafer style.
3. Piston and Spring Assembly: Stainless steel, tamper proof, self cleaning.
5. Trim: Dual pressure/temperature test plugs across flow control cartridge.
4. Identification Tag: Marked with zone identification, valve number, and flow rate.
5. Size: NPS 2 1/2" and larger; same size as pipe in which installed.
6. Performance: Maintain constant flow, plus or minus 5 percent over system pressure fluctuations.
6. Minimum CWP Rating: 150 psig.
7. Maximum Operating Temperature: 250 deg F.

E. Combination Automatic Flow-Control Valve / Isolation Ball Valve:

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

   a. Flow Design Inc.
   b. Griswold Controls.

2. Body: Forged or cast brass.
3. Connections: Threaded with union inlet.
4. Piston and Spring Assembly: Stainless steel, tamper proof, self cleaning, and removable.
5. Trim: Dual pressure/temperature test plugs across flow control cartridge.
6. Combination Assemblies: Include bonze or brass-alloy ball valve and automatic flow control valve.
7. Identification Tag: Marked with zone identification, valve number, and flow rate.

8. Size: NPS 2" and smaller; same as pipe in which installed.
9. Performance: Maintain constant flow, plus or minus 5 percent over system pressure fluctuations.
7. Minimum CWP Rating: **175 psig**.
10. Maximum Operating Temperature: **200 deg F**.

F. Combination Strainer / Isolation Ball Valve:

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

   a. Flow Design Inc.
   b. Griswold Controls.

2. Body: Forged or cast brass.
3. Connections: Threaded with union inlet.
4. Combination Assemblies: Include bronze or brass-alloy ball valve, union and strainer.
5. Strainer: 20 mesh stainless steel; provide drain valve with hose bibb adaptor and cap on strainer port. Provide a pressure/temperature test plug at the strainer inlet and outlet.
6. Valve: Nickel-plated brass ball with EPDM O-rings behind the seals.
7. Size: NPS 2" and smaller.
8. Minimum CWP Rating: 275 psig.
9. Maximum Operating Temperature: **250 deg F**.

G. Combination Union / Isolation Ball Valve:

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

   a. Flow Design Inc.
   b. Griswold Controls.

2. Body: Forged or cast brass.
3. Connections: Threaded with union inlet.
4. Combination Assemblies: Include bronze or brass-alloy ball valve and union.
5. Union: Provide union with four ¼" body tappings with brass end connections. Union seal shall be EPDM O-rings. Provide an automatic air vent in the top tapping and a pressure/temperature test plug.
6. Valve: Nickel-plated brass ball with EPDM O-rings behind the seals.
7. Size: NPS 2" and smaller.
8. Minimum CWP Rating: 275 psig.
8. Maximum Operating Temperature: 250 **deg** F.

H. Isolation Union:

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

   a. Flow Design Inc.
   b. Griswold Controls.

2. Body: Forged or cast brass.
3. Connections: Threaded.
4. Union: Provide union with four ¼" body tappings with brass end connections. Union seal shall be EPDM O-rings. Provide a pressure/temperature test plug.
5. Size: NPS 2" and smaller.
6. Minimum CWP Rating: 275 psig.
7. Maximum Operating Temperature: 250 deg F.

1.3 HYDRONIC COIL PACKAGES

A. Provide the following arrangements for individual coil connections 2" NPS and smaller where indicated on the drawings.

1. Supply Side: Provide Combination Strainer / Isolation Ball Valve.
2. Return Side:
   a. Modulating Control (Two Way): Provide combination union / isolation ball valve on leaving side of control valve and isolation union on inlet side of control valve. Provide pressure independent control valve specified in section 230900.
   b. Modulating Control (Three Way): Provide combination automatic fow control valve / isolation ball valve on leaving side of control valve. Provide control valve specified in section 230900.

3. Provide hose kits complete with flame retardant hose.

2.5 AIR CONTROL DEVICES

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

1. Amtrol, Inc.
2. Bell & Gossett Domestic Pump; a division of ITT Industries.
3. Taco.

B. Manual Air Vents:

1. Body: Bronze.
2. Internal Parts: Nonferrous.
3. Operator: Screwdriver or thumbscrew.
4. Inlet Connection: NPS 1/2 (DN 15).
5. Discharge Connection: NPS 1/8 (DN 6).
6. CWP Rating: 150 psig (1035 kPa).
7. Maximum Operating Temperature: 225 deg F (107 deg C).

C. Automatic Air Vents:

1. Body: Bronze or cast iron.
2. Internal Parts: Nonferrous.
3. Operator: Noncorrosive metal float.
4. Inlet Connection: NPS 1/2 (DN 15).

5. Discharge Connection: NPS 1/4 (DN 8).
6. CWP Rating: 150 psig (1035 kPa).
7. Maximum Operating Temperature: 240 deg F (116 deg C).

8. Pressure Drop: Provide high velocity model with a maximum pressure drop of 2.0 psi at a velocity of 11 fps.
4. Removable Head: Vessel head shall be removable to allow removal of medium assembly and cleaning of vessel interior.

2.6 HYDRONIC PIPING SPECIALTIES

A. Y-Pattern Strainers:

1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
3. Strainer Screen: 40 -mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 125 psig (860 kPa).

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

B. Hot-water heating piping, NPS 2 DN 50 and smaller, shall be any of the following:

1. Type L (B)drawn-temper copper tubing, wrought-copper fittings, and soldered joints.
2. Schedule 40 steel pipe; Class 150, malleable-iron fittings; cast-iron flanges and flange fittings; and threaded joints.

A. Hot-water heating piping, **NPS** 2-1/**2 (DN** 65**)** and larger, shall bethe following:
1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

C. Chilled-water piping, NPS 2 DN 50 and smaller, shall be any of the following:

1. Type L (B), drawn-temper copper tubing, wrought-copper fittings, and soldered joints.
2. Schedule 40 steel pipe; Class 150, malleable-iron fittings; cast-iron flanges and flange fittings; and threaded joints.

B. Chilled-water piping, **NPS 2-1/2 (DN 65)** and larger, shall bethe following:

3. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

C. Condensate-Drain Piping: Type DWV, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.

D. Air-Vent Piping:

1. Inlet: Same as service where installed.
2. Outlet: Type K (A), annealed-temper copper tubing with soldered or flared joints.

3.2 VALVE APPLICATIONS

A. Install shutoff-duty valves at each branch connection to supply mains, and at supply connection to each piece of equipment.

3.3 PIPING INSTALLATIONS

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicate piping locations and arrangements if such were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

B. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.

C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

E. Install piping to permit valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

H. Install fittings for changes in direction and branch connections.

I. Install piping to allow application of insulation.

J. Select system components with pressure rating equal to or greater than system operating pressure.

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, NPS 3/4 (DN 20) ball valve, and short NPS 3/4 (DN 20) threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.

O. Install branch connections to mains using tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.

P. Install valves according to Division 23 Section "General-Duty Valves for HVAC Piping."

Q. Install unions in piping, NPS 2 (DN 50) and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, NPS 2-1/2 (DN 65) and larger, at final connections of equipment and elsewhere as indicated.

S. Install strainers on inlet side of each control valve, and elsewhere as indicated. Install NPS 3/4 (DN 20) nipple and ball valve in blowdown connection of strainers NPS 2 (DN 50) and larger. Match size of strainer blowoff connection for strainers smaller than NPS 2 (DN 50).

T. Install expansion loops, expansion joints, anchors, and pipe alignment guides as specified in Division 23 Section "Expansion Fittings and Loops for HVAC Piping."

U. Identify piping as specified in Division 23 Section "Identification for HVAC Piping and Equipment."

V. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Division 23 Section "Sleeves and Sleeve Seals for HVAC Piping."

W. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Division 23 Section "Escutcheons for HVAC Piping."

3.4 HANGERS AND SUPPORTS

A. Hanger, support, and anchor devices are specified in Division 23 Section "Hangers and Supports for HVAC Piping and Equipment." Comply with the following requirements for maximum spacing of supports.

B. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual horizontal piping.
2. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.

C. Install hangers for steel piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4 (DN 20): Maximum span, 7 feet (2.1 m); minimum rod size, 1/4 inch (6.4 mm).
2. NPS 1 (DN 25): Maximum span, 7 feet (2.1 m); minimum rod size, 1/4 inch (6.4 mm).
3. NPS 1-1/2 (DN 40): Maximum span, 9 feet (2.7 m); minimum rod size, 3/8 inch (10 mm).
4. NPS 2 (DN 50): Maximum span, 10 feet (3 m); minimum rod size, 3/8 inch (10 mm).
5. NPS 2-1/2 (DN 65): Maximum span, 11 feet (3.4 m); minimum rod size, 3/8 inch (10 mm).
6. NPS 3 (DN 80): Maximum span, 12 feet (3.7 m); minimum rod size, 3/8 inch (10 mm).
7. NPS 4 (DN 100): Maximum span, 14 feet (4.3 m); minimum rod size, 1/2 inch (13 mm).
8. NPS 6 (DN 150): Maximum span, 17 feet (5.2 m); minimum rod size, 1/2 inch (13 mm).

D. Install hangers for drawn-temper copper piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4 (DN 20): Maximum span, 5 feet (1.5 m); minimum rod size, 1/4 inch (6.4 mm).
2. NPS 1 (DN 25): Maximum span, 6 feet (1.8 m); minimum rod size, 1/4 inch (6.4 mm).
3. NPS 1-1/2 (DN 40): Maximum span, 8 feet (2.4 m); minimum rod size, 3/8 inch (10 mm).
4. NPS 2 (DN 50): Maximum span, 8 feet (2.4 m); minimum rod size, 3/8 inch (10 mm).

3.5 PIPE JOINT CONSTRUCTION

A. Join pipe and fittings according to the following requirements and Division 23 Sections specifying piping systems.

B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

D. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.

E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

F. Welded Joints: Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.

G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

3.6 HYDRONIC SPECIALTIES INSTALLATION

A. Install manual air vents at high points in piping, and elsewhere as required for system air venting.

B. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Manual vents at heat-transfer coils and elsewhere as required for air venting.

3.7 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install ports for pressure gages and thermometers at coil inlet and outlet connections according to Division 23 Section "Meters and Gages for HVAC Piping."

3.8 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:

1. Leave joints, including welds, uninsulated and exposed for examination during test.
2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:

1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
3. Isolate expansion tanks and determine that hydronic system is full of water.
4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.
6. Prepare written report of testing.

C. Perform the following before operating the system:

1. Open manual valves fully.
2. Inspect pumps for proper rotation.
3. Set makeup pressure-reducing valves for required system pressure.

4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Inspect and set operating temperatures of hydronic equipment to specified values.
7. Verify lubrication of motors and bearings.

END OF SECTION 232113

SECTION 232923 - VARIABLE-FREQUENCY MOTOR CONTROLLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes separately enclosed, pre-assembled, combination VFCs, rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.

B. Related Sections:

1. Section 262419 "Motor-Control Centers" for VFCs installed in motor-control centers.

1.3 DEFINITIONS

A. BAS: Building automation system.

B. CE: Conformite Europeene (European Compliance).

C. CPT: Control power transformer.

D. EMI: Electromagnetic interference.

E. IGBT: Insulated-gate bipolar transistor.

F. LAN: Local area network.

G. LED: Light-emitting diode.

H. MCP: Motor-circuit protector.

I. NC: Normally closed.

J. NO: Normally open.

K. OCPD: Overcurrent protective device.

L. PCC: Point of common coupling.

M. PID: Control action, proportional plus integral plus derivative.

N. PWM: Pulse-width modulated.

O. RFI: Radio-frequency interference.

P. TDD: Total demand (harmonic current) distortion.

Q. THD(V): Total harmonic voltage demand.

R. VFC: Variable-frequency motor controller.

1.4 ACTION SUBMITTALS

A. Product Data: For each type and rating of VFC indicated. Include features, performance, electrical ratings, operating characteristics, shipping and operating weights, and furnished specialties and accessories.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around VFCs. Show VFC layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.

B. Qualification Data: For qualified testing agency.

C. Product Certificates: For each VFC, from manufacturer.

D. Harmonic Analysis Study and Report: Comply with IEEE 399 and NETA Acceptance Testing Specification; identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze possible operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at each VFC to specified levels.

E. Source quality-control reports.

F. Field quality-control reports.

G. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For VFCs to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

1. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and MCP trip settings.
2. Manufacturer's written instructions for setting field-adjustable overload relays.

3. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
4. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.

1.7 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
2. Control Power Fuses: Equal to 10 percent of quantity installed for each size and type, but no fewer than two of each size and type.
3. Indicating Lights: Two of each type and color installed.
4. Auxiliary Contacts: Furnish one spare(s) for each size and type of magnetic controller installed.
5. Power Contacts: Furnish three spares for each size and type of magnetic contactor installed.

1.8 QUALITY ASSURANCE

A. Testing Agency Qualifications: Member company of NETA or an NRTL.

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

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Comply with NFPA 70.

D. IEEE Compliance: Fabricate and test VFC according to IEEE 344 to withstand seismic forces defined in Section 260548 "Vibration and Seismic Controls for Electrical Systems."

1.9 DELIVERY, STORAGE, AND HANDLING

A. Store in space that is enclosed, air conditioned and free of construction born debris and dust.

B. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside controllers and connect factory-installed space heaters to temporary electrical service.

1.10 PROJECT CONDITIONS

A. Environmental Limitations: Rate equipment for continuous operation, capable of driving full load without derating, under the following conditions unless otherwise indicated:

1. Ambient Temperature: Not less than 14 deg F (minus 10 deg C) and not exceeding 104 deg F (40 deg C).
2. Ambient Storage Temperature: Not less than minus 4 deg F (minus 20 deg C) and not exceeding 140 deg F (60 deg C)
3. Humidity: Less than 95 percent (noncondensing).
4. Altitude: Not exceeding 3300 feet (1005 m).

B. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:

1. Notify Owner no fewer than five days in advance of proposed interruption of electrical systems.
2. Indicate method of providing temporary electrical service.
3. Do not proceed with interruption of electrical systems without Owner's written permission.
4. Comply with NFPA 70E.

C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFCs, including clearances between VFCs, and adjacent surfaces and other items.

1.11 COORDINATION

A. Coordinate features of motors, load characteristics, installed units, and accessory devices to be compatible with the following:

1. Torque, speed, and horsepower requirements of the load.
2. Ratings and characteristics of supply circuit and required control sequence.
3. Ambient and environmental conditions of installation location.

B. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.

1.12 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace VFCs that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

A. Basis-of-Design Product: Subject to compliance with requirements, provide ABB; ACH 550 or comparable product by one of the following:

1. Danfoss Inc.; Danfoss Drives Div.

2. Siemens Energy & Automation, Inc.
3. Square D; a brand of Schneider Electric.
4. Yaskawa Electric America, Inc; Drives Division.

B. General Requirements for VFCs: Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508C .

C. Application: Variable torque .

D. VFC Description: Variable-frequency power converter (rectifier, dc bus, and IGBT, PWM inverter) factory packaged in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.

1. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
2. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

E. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

F. Output Rating: Three-phase; 10 to 60 Hz, with voltage proportional to frequency throughout voltage range ; maximum voltage equals input voltage.

G. Unit Operating Requirements:

1. Input AC Voltage Tolerance: Plus 10 and minus 15 percent of VFC input voltage rating.
2. Input AC Voltage Unbalance: Not exceeding 5 percent.
3. Input Frequency Tolerance: Plus or minus 3 percent of VFC frequency rating.
4. Minimum Efficiency: 97 percent at 60 Hz, full load.
5. Minimum Displacement Primary-Side Power Factor: 98 percent under any load or speed condition.
6. Minimum Short-Circuit Current (Withstand) Rating: 100 kA.
7. Ambient Temperature Rating: Not less than 14 deg F (minus 10 deg C) and not exceeding 104 deg F (40 deg C).
8. Ambient Storage Temperature Rating: Not less than minus 4 deg F (minus 20 deg C) and not exceeding 140 deg F (60 deg C)
9. Humidity Rating: Less than 95 percent (noncondensing).
10. Altitude Rating: Not exceeding 3300 feet (1005 m).
11. Vibration Withstand: Comply with IEC 60068-2-6.
12. Overload Capability: 1.1 times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.
13. Starting Torque: Minimum 100 percent of rated torque from 3 to 60 Hz.
14. Speed Regulation: Plus or minus 0.1 percent.
15. Output Carrier Frequency: Selectable; 0.5 to 15 kHz.
16. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.

H. Inverter Logic: Microprocessor based, 32 bit, isolated from all power circuits.

I. Isolated Control Interface: Allows VFCs to follow remote-control signal over a minimum 40:1 speed range.

1. Signal: Electrical.

J. Internal Adjustability Capabilities:

1. Minimum Speed: 5 to 25 percent of maximum rpm.
2. Maximum Speed: 80 to 100 percent of maximum rpm.
3. Acceleration: 0.1 to 6,000 seconds.
4. Deceleration: 0.1 to 6,000 seconds.
5. Current Limit: 30 to minimum of 150 percent of maximum rating.

K. Self-Protection and Reliability Features:

1. Input transient protection by means of surge suppressors to provide three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
2. Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
3. Under- and overvoltage trips.
4. Inverter overcurrent trips.
5. VFC and Motor Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing VFC overtemperature and motor overload alarm and trip; settings selectable via the keypad; NRTL approved.
6. Critical frequency rejection, with three selectable, adjustable deadbands.
7. Instantaneous line-to-line and line-to-ground overcurrent trips.
8. Loss-of-phase protection.
9. Reverse-phase protection.
10. Short-circuit protection.
11. Motor overtemperature fault.

L. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.

M. Bidirectional Autospeed Search: Capable of starting VFC into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.

N. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.

O. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.

P. Integral Input Disconnecting Means and OCPD: NEMA AB 1, instantaneous-trip circuit breaker with pad-lockable, door-mounted handle mechanism.

1. Disconnect Rating: Not less than 115 percent of NFPA 70 motor full-load current rating or VFC input current rating, whichever is larger.
2. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
3. NC alarm contact that operates only when circuit breaker has tripped.

2.2 CONTROLS AND INDICATION

A. Status Lights: Door-mounted LED indicators displaying the following conditions:

1. Power on.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
6. External fault.

B. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.

1. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
2. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.

    a. Control Authority: Supports at least four conditions: Off, local manual control at VFC, local automatic control at VFC, and automatic control through a remote source.

C. Historical Logging Information and Displays:

1. Real-time clock with current time and date.
2. Running log of total power versus time.
3. Total run time.
4. Fault log, maintaining last four faults with time and date stamp for each.

D. Indicating Devices: Digital display mounted flush in VFC door and connected to display VFC parameters including, but not limited to:

1. Output frequency (Hz).
2. Motor speed (rpm).
3. Motor status (running, stop, fault).
4. Motor current (amperes).
5. Motor torque (percent).
6. Fault or alarming status (code).
7. PID feedback signal (percent).
8. DC-link voltage (V dc).
9. Set point frequency (Hz).
10. Motor output voltage (V ac).

E. Control Signal Interfaces:

1. Electric Input Signal Interface:

   a. A minimum of two programmable analog inputs: 0- to 10-V dc or 4- to 20-mA dc Operator-selectable "x"- to "y"-mA dc .
   b. A minimum of six multifunction programmable digital inputs.

2. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:

   a. 0- to 10-V dc.
   b. 4- to 20-mA dc.
   c. Potentiometer using up/down digital inputs.

3. Output Signal Interface: A minimum of one programmable analog output signal(s) (0- to 10-V dc or 4- to 20-mA dc operator-selectable "x"- to "y"-mA dc), which can be configured for any of the following:

   a. Output frequency (Hz).
   b. Output current (load).
   c. DC-link voltage (V dc).
   d. Motor torque (percent).
   e. Motor speed (rpm).
   f. Set point frequency (Hz).

4. Remote Indication Interface: A minimum of two programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:

   a. Motor running.
   b. Set point speed reached.
   c. Fault and warning indication (overtemperature or overcurrent).
   d. PID high- or low-speed limits reached.

F. PID Control Interface: Provides closed-loop set point, differential feedback control in response to dual feedback signals. Allows for closed-loop control of fans and pumps for pressure, flow, or temperature regulation.

1. Number of Loops: One .

G. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display VFC status and alarms and energy usage. Allows VFC to be used with an external system within a multidrop LAN configuration; settings retained within VFC's nonvolatile memory.

1. Network Communications Ports: Ethernet and RS-422/485 .
2. Embedded BAS Protocols for Network Communications: ASHRAE 135 BACnet, Johnson Metasys N2, Modbus/Memobus, and Siemens System 600 APOGEE ; protocols accessible via the communications ports.

2.3 LINE CONDITIONING AND FILTERING

A. Input Line Conditioning: Based on the harmonic analysis study and report, provide input filtering, as required, to limit TDD and THD(V) at the defined PCC per IEEE 519 .

B. Input Line Conditioning: 3% DC Bus Reactor.

C. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for Category C2.

2.4 BYPASS SYSTEMS

A. Bypass Operation: Safely transfers motor between power converter output and bypass circuit, manually, automatically, or both. Selector switches set modes and indicator lights indicate mode selected. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter.

B. Bypass Mode: Field-selectable automatic or manual, allows local and remote transfer between power converter and bypass contactor and retransfer, either via manual operator interface or automatic control system feedback.

C. Bypass Controller: Three-contactor-style bypass allows motor operation via the power converter or the bypass controller; with input isolating switch and barrier arranged to isolate the power converter input and output and permit safe testing and troubleshooting of the power converter, both energized and de-energized, while motor is operating in bypass mode.

1. Bypass Contactor: Load-break, NEMA-rated contactor.
2. Input and Output Isolating Contactors: Non-load-break, NEMA-rated contactors.
3. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

D. Bypass Contactor Configuration: Reduced-voltage (autotransformer) type.

1. NORMAL/BYPASS selector switch.
2. HAND/OFF/AUTO selector switch.
3. NORMAL/TEST Selector Switch: Allows testing and adjusting of VFC while the motor is running in the bypass mode.
4. Contactor Coils: Pressure-encapsulated type with coil transient suppressors.
    a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
    b. Power Contacts: Totally enclosed, double break, and silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
5. Control Circuits: 120 -V ac; obtained from integral CPT, with primary and secondary fuses , with CPT of sufficient capacity to operate all integral devices and remotely located pilot, indicating, and control devices.

a. CPT Spare Capacity: 100 VA.

6. Overload Relays: NEMA ICS 2.

a. Solid-State Overload Relays:

1) Switch or dial selectable for motor-running overload protection.
2) Sensors in each phase.
3) Class 10/20 selectable tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.
4) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
5) Analog communication module.

b. NC isolated overload alarm contact.
c. External overload reset push button.

2.5 OPTIONAL FEATURES

A. Sleep Function: Senses a minimal deviation of a feedback signal and stops the motor. On an increase in speed-command signal deviation, VFC resumes normal operation.

B. Firefighter's Override (Smoke Purge) Input: On a remote contact closure from smoke-control fan controller , this password-protected input:

1. Overrides all other local and external inputs (analog/digital, serial communication, and all keypad commands).
2. Forces VFC to operate motor, without any other run or speed command, at a field-adjustable, preset speed.
3. Causes display of Override Mode on the VFC display.
4. Reset VFC to normal operation on removal of override signal automatically .

C. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer.

2.6 ENCLOSURES

A. VFC Enclosures: NEMA 250, to comply with environmental conditions at installed location.

1. Dry and Clean Indoor Locations: Type 1 .
2. Outdoor Locations: Type 3R .
3. Other Wet or Damp Indoor Locations: Type 4 .
4. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.

B. Plenum Rating: UL 1995; NRTL certification label on enclosure, clearly identifying VFC as "Plenum Rated."

2.7 ACCESSORIES

A. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in VFC enclosure cover unless otherwise indicated.

1. Push Buttons, Pilot Lights, and Selector Switches: Standard-duty, oiltight type.

a. Push Buttons: Covered types; momentary.
b. Pilot Lights: LED types; ; push to test.
c. Selector Switches: Rotary type.

B. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.

1. Current Transformers: Continuous current rating, basic impulse insulating level (BIL) rating, burden, and accuracy class suitable for connected circuitry. Comply with IEEE C57.13.

C. Breather and drain assemblies, to maintain interior pressure and release condensation in NEMA 250, Type 4, Type 4X or Type 12 enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.

D. Space heaters, with NC auxiliary contacts, to mitigate condensation in NEMA 250, Type 3R, Type 4X or Type 12 enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.

E. Cooling Fan and Exhaust System: For NEMA 250, Type 1 ; UL 508 component recognized: Supply fan, with stainless steel intake and exhaust grills and filters; 120 -V ac; obtained from integral CPT .

F. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.

2.8 SOURCE QUALITY CONTROL

A. Testing: Test and inspect VFCs according to requirements in NEMA ICS 61800-2 .

1. Test each VFC while connected to a motor that is comparable to that for which the VFC is rated.
2. Verification of Performance: Rate VFCs according to operation of functions and features specified.

B. VFCs will be considered defective if they do not pass tests and inspections.

C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas, surfaces, and substrates to receive VFCs, with Installer present, for compliance with requirements for installation tolerances, and other conditions affecting performance.

B. Examine VFC before installation. Reject VFCs that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFC installation.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 HARMONIC ANALYSIS STUDY

A. Perform a harmonic analysis study to identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze possible operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at each VFC to specified levels.

B. Prepare a harmonic analysis study and report complying with IEEE 399 and NETA Acceptance Testing Specification.

3.3 INSTALLATION

A. Coordinate layout and installation of VFCs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Wall-Mounting Controllers: Install VFCs on walls with tops at uniform height and with disconnect operating handles not higher than 79 inches (2000 mm) above finished floor unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not on walls, provide freestanding racks complying with Section 260529 "Hangers and Supports for Electrical Systems."

C. Floor-Mounting Controllers: Install VFCs on 4-inch (100-mm) nominal thickness concrete base. Comply with requirements for concrete base specified in Section 033053.1 "Miscellaneous Cast-in-Place Concrete for Mechanical and Electrical Systems."

1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.

D. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

E. Install fuses in control circuits if not factory installed. Comply with requirements in Section 262813 "Fuses."

F. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.

G. Comply with NECA 1.

3.4 IDENTIFICATION

A. Identify VFCs, components, and control wiring. Comply with requirements for identification specified in Section 230553 "Identification for HVAC Systems."

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label each VFC with engraved nameplate.
3. Label each enclosure-mounted control and pilot device.

B. Operating Instructions: Frame printed operating instructions for VFCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.

3.5 CONTROL WIRING INSTALLATION

A. Install wiring between VFCs and remote devices and facility's central-control system. Comply with requirements in Section 260523 "Control-Voltage Electrical Power Cables."

B. Bundle, train, and support wiring in enclosures.

C. Connect selector switches and other automatic control devices where applicable.

1. Connect selector switches to bypass only those manual- and automatic control devices that have no safety functions when switches are in manual-control position.
2. Connect selector switches with control circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

3.6 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

C. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

D. Acceptance Testing Preparation:

1. Test insulation resistance for each VFC element, bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

E. Tests and Inspections:

1. Inspect VFC, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
2. Test insulation resistance for each VFC element, component, connecting motor supply, feeder, and control circuits.
3. Test continuity of each circuit.
4. Verify that voltages at VFC locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify Engineer before starting the motor(s).
5. Test each motor for proper phase rotation.
6. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

7. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

F. VFCs will be considered defective if they do not pass tests and inspections.

G. Prepare test and inspection reports, including a certified report that identifies the VFC and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.7 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.

3.8 ADJUSTING

A. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.

B. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.

C. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to six times the motor nameplate full-load amperes

and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify Engineer before increasing settings.

D. Set the taps on reduced-voltage autotransformer controllers.

E. Set field-adjustable circuit-breaker trip ranges as specified in Section 260573 "Overcurrent Protective Device Coordination Study."

F. Set field-adjustable pressure switches.

3.9 PROTECTION

A. Replace VFCs whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.10 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, reprogram, and maintain VFCs.

END OF SECTION 232923

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SECTION 233113 - METAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Single-wall rectangular ducts and fittings.
2. Single-wall round ducts and fittings.
3. Sheet metal materials.
4. Sealants and gaskets.
5. Hangers and supports.

B. Related Sections:

1. Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
2. Division 23 Section "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.

1.3 PERFORMANCE REQUIREMENTS

A. Structural Performance: Duct hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"

B. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of the following products:

1. Liners and adhesives.
2. Sealants and gaskets.

1.5 QUALITY ASSURANCE

A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-up."

B. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

PART 2 - PRODUCTS

2.1 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.2 SINGLE-WALL ROUND DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. Transverse Joints in Ducts Larger Than 32 in Diameter: Flanged.

C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. Fabricate flat-oval ducts larger than 72 inches (1830 mm) in width (major dimension) with butt-welded longitudinal seams.

D. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 SHEET METAL MATERIALS

A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G60 (Z180) .
2. Finishes for Surfaces Exposed to View: Mill phosphatized.

C. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; galvanized.

D. Tie Rods: Galvanized steel, 1/4-inch (6-mm) minimum diameter for lengths 36 inches (900 mm) or less; 3/8-inch (10-mm) minimum diameter for lengths longer than 36 inches (900 mm).

2.4 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.

B. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive and negative.
8. Service: Indoor or outdoor.

9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

C. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.
6. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

D. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

E. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg (0.14 L/s per sq. m at 250 Pa) and shall be rated for 10-inch wg (2500-Pa) static-pressure class, positive or negative.
2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.

2.5 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1 (Table 5-1M), "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."

D. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.

E. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.

F. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

G. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

H. Trapeze and Riser Supports:

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

C. Install round ducts in maximum practical lengths.

D. Install ducts with fewest possible joints.

E. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

H. Install ducts with a clearance of 1 inch (25 mm), plus allowance for insulation thickness.

I. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

J. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches (38 mm).

K. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Division 23 Section "Air Duct Accessories" for fire and smoke dampers.

L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."

3.2 INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

D. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 DUCT SEALING

A. Seal ducts to the following seal classes according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":

1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
2. Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg (500 Pa) and Lower: Seal Class A.
3. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg (500 Pa): Seal Class A.
4. Unconditioned Space, Exhaust Ducts: Seal Class A.
5. Unconditioned Space, Return-Air Ducts: Seal Class A.
6. Conditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg (500 Pa) and Lower: Seal Class A.
7. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg (500 Pa): Seal Class A.
8. Conditioned Space, Exhaust Ducts: Seal Class A.
9. Conditioned Space, Return-Air Ducts: Seal Class A.

3.4 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches (100 mm) thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches (100 mm) thick.

C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1 (Table 5-1M), "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches (610 mm) of each elbow and within 48 inches (1200 mm) of each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet (5 m).

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.5 CONNECTIONS

A. Make connections to equipment with flexible connectors complying with Division 23 Section "Air Duct Accessories."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.6 PAINTING

A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Division 09 painting Sections.

3.7 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Leakage Tests:

1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
2. Test the following systems:
   a. Supply Ducts with a Pressure Class of 3-Inch wg (750 Pa) or Higher: Test representative duct sections, selected by Engineer from sections installed, totaling no less than 50 percent of total installed duct area for each designated pressure class.
   b. Laboratory Exhaust Ducts with a Pressure Class of 3-Inch wg (750 Pa) or Higher: Test representative duct sections totaling no less than 100 percent of total installed duct area for each designated pressure class.
3. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
4. Test for leaks before applying external insulation.
5. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
6. Give seven days' advance notice for testing.

C. Duct System Cleanliness Tests:

1. Visually inspect duct system to ensure that no visible contaminants are present.

2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."

    a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

D. Duct system will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.8 DUCT CLEANING

A. Clean new duct system(s) before testing, adjusting, and balancing.

B. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Division 23 Section "Air Duct Accessories" for access panels and doors.
2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
3. Remove and reinstall ceiling to gain access during the cleaning process.

C. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

D. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

E. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for wash-down procedures.
7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

3.9 START UP

A. Air Balance: Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC."

3.10 DUCT SCHEDULE

A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:

B. Supply Ducts:

1. Ducts Connected to Terminal Units :

2. Pressure Class: Positive 2-inch wg (500 Pa) Ducts Connected to Constant-Volume Air-Handling Units :

   a. Pressure Class: Positive 2-inch wg (500 Pa) .

3. Ducts Connected to Variable-Air-Volume Air-Handling Units :
   a. Pressure Class: Positive 3-inch wg (750 Pa) SMACNA Leakage Class for Rectangular: 6.
   b. SMACNA Leakage Class for Round: 6 .

4. Ducts Connected to Equipment Not Listed Above:

   a. Pressure Class: Positive 2-inch wg (500 Pa) .

C. Return Ducts:

1. Ducts Connected to Air-Handling Units :

   a. Pressure Class: Positive or negative 2-inch wg (500 Pa) .

2. Ducts Connected to Equipment Not Listed Above:

a. Pressure Class: Positive or negative 2-inch wg (500 Pa) .

D. Exhaust Ducts:

1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:

a. Pressure Class: Negative 2-inch wg (500 Pa) .

2. Ducts Connected to Air-Handling Units :

a. Pressure Class: Positive or negative 2-inch wg (500 Pa) .

3. Ducts Connected to Equipment Not Listed Above:

a. Pressure Class: Positive or negative 2-inch wg (500 Pa) .

E. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:

1. Ducts Connected to Air-Handling Units :

a. Pressure Class: Positive or negative 2-inch wg (500 Pa) .

2. Ducts Connected to Equipment Not Listed Above:

a. Pressure Class: Positive or negative 2-inch wg (500 Pa) .

F. Intermediate Reinforcement:

1. Galvanized-Steel Ducts: Galvanized steel .

G. Elbow Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."

a. Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
b. Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

2. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."

a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.
1) Radius-to Diameter Ratio: 1.5.

b. Round Elbows, 12 Inches (305 mm) and Smaller in Diameter: Stamped or pleated.
c. Round Elbows, 14 Inches (356 mm) and Larger in Diameter: Welded.

H. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."

   a. Rectangular Main to Rectangular Branch: 45-degree entry.
   b. Rectangular Main to Round Branch45-degree side take-off.

2. Round and Flat Oval: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.

   a. Velocity 1000 fpm (5 m/s) or Lower: Conical tap.
   b. Velocity 1000 to 1500 fpm (5 to 7.6 m/s): Conical tap.
   c. Velocity 1500 fpm (7.6 m/s) or Higher: 45-degree lateral.

END OF SECTION 233113

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SECTION 233300 - AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:
   1. Manual volume dampers.
   2. Control dampers.
   3. Fire dampers.
   4. Flange connectors.
   5. Turning vanes.
   6. Duct-mounted access doors.
   7. Flexible connectors.
   8. Flexible ducts.
   9. Duct accessory hardware.

B. Related Requirements:

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1.4 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 ASSEMBLY DESCRIPTION

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

2.2 MATERIALS

A. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G60 (Z180) .
2. Exposed-Surface Finish: Mill phosphatized.

B. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

C. Tie Rods: Galvanized steel, 1/4-inch (6-mm) minimum diameter for lengths 36 inches (900 mm) or less; 3/8-inch (10-mm) minimum diameter for lengths longer than 36 inches (900 mm).

2.3 MANUAL VOLUME DAMPERS

A. Standard, Steel, Manual Volume Dampers:

1. Standard leakage rating, with linkage outside airstream.
2. Suitable for horizontal or vertical applications.
3. Frames:

   a. Frame: Hat-shaped, 0.6-inch- (2.4-mm-) thick, galvanized sheet steel .
   b. Mitered and welded corners.
   c. Flanges for attaching to walls and flangeless frames for installing in ducts.

4. Blades:

   a. Multiple or single blade.
   b. Parallel- or opposed-blade design.
   c. Stiffen damper blades for stability.
   d. Galvanized -steel, 0.064 inch (1.62 mm) thick.

5. Blade Axles: Galvanized steel .
6. Bearings:

   a. Molded synthetic .
   b. Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

7. Tie Bars and Brackets: Galvanized steel.

B. Jackshaft:

1. Size: 1-inch (25-mm) diameter.
2. Material: Galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.
3. Length and Number of Mountings: As required to connect linkage of each damper in multiple-damper assembly.

C. Damper Hardware:

1. Zinc-plated, die-cast core with dial and handle made of 3/32-inch- (2.4-mm-) thick zinc-plated steel, and a 3/4-inch (19-mm) hexagon locking nut.
2. Include center hole to suit damper operating-rod size.
3. Include elevated platform for insulated duct mounting.

2.4 CONTROL DAMPERS

A. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.

B. Frames:

1. Hat shaped.
2. 0.064-inch- (2.4-mm-) thick, galvanized sheet steel .
3. Mitered and welded corners.

C. Blades:

1. Multiple blade with maximum blade width of 6 inches (152 mm) .
2. Opposed-blade design.
3. Galvanized-steel .
4. Blade Edging: Closed-cell neoprene .

D. Blade Axles: 1/2-inch- (13-mm-) diameter; galvanized steel ; blade-linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.

1. Operating Temperature Range: From minus 40 to plus 200 deg F (minus 40 to plus 93 deg C).

E. Bearings:

1. Stainless-steel sleeve.
2. Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
3. Thrust bearings at each end of every blade.

2.5 FIRE DAMPERS

A. Type: Static ; rated and labeled according to UL 555 by an NRTL.

B. Fire Rating: 1-1/2 and 3 hours.

C. Frame: Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.

D. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.

1. Minimum Thickness: 0.138 inch (3.5 mm) thick, as indicated, and of length to suit application.

2. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.

E. Mounting Orientation: Vertical or horizontal as indicated.

F. Blades: Roll-formed, interlocking, 0.034-inch- (0.85-mm-) thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- (0.85-mm-) thick, galvanized-steel blade connectors.

G. Horizontal Dampers: Include blade lock and stainless-steel closure spring.

H. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) rated, fusible links.

2.6 TURNING VANES

A. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

1. Acoustic Turning Vanes: Fabricate airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.

B. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 4-3, "Vanes and Vane Runners," and 4-4, "Vane Support in Elbows."

C. Vane Construction: Double wall.

2.7 DUCT-MOUNTED ACCESS DOORS

A. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 7-2 (7-2M), "Duct Access Doors and Panels," and 7-3, "Access Doors - Round Duct."

1. Door:

a. Double wall, rectangular.
b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
c. Hinges and Latches: 1-by-1-inch (25-by-25-mm)butt or piano hinge and cam latches.
d. Fabricate doors airtight and suitable for duct pressure class.

2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
3. Number of Hinges and Locks:

a. Access Doors Less Than 12 Inches (300 mm) Square: No hinges and two sash locks.
b. Access Doors up to 18 Inches (460 mm) Square: Two hinges Continuous and two sash locks.

c. Access Doors up to 24 by 48 Inches (600 by 1200 mm): Three hinges Continuous and two compression latches.
d. Access Doors Larger Than 24 by 48 Inches (600 by 1200 mm): Four hinges Continuous and two compression latches with outside and inside handles.

2.8 DUCT ACCESS PANEL ASSEMBLIES

A. Labeled according to UL 1978 by an NRTL.

B. Panel and Frame: Minimum thickness 0.0428-inch (1.1-mm) stainless steel.

C. Fasteners: Stainless steel. Panel fasteners shall not penetrate duct wall.

D. Gasket: Comply with NFPA 96; grease-tight, high-temperature ceramic fiber, rated for minimum 2000 deg F (1093 deg C).

E. Minimum Pressure Rating: 10-inch wg (2500 Pa), positive or negative.

2.9 FLEXIBLE CONNECTORS

A. Materials: Flame-retardant or noncombustible fabrics.

B. Coatings and Adhesives: Comply with UL 181, Class 1.

C. Metal-Edged Connectors: Factory fabricated with a fabric strip 5-3/4 inches (146 mm) wide attached to two strips of 2-3/4-inch- (70-mm-) wide, 0.028-inch- (0.7-mm-) thick, galvanized sheet steel or 0.032-inch- (0.8-mm-) thick aluminum sheets. Provide metal compatible with connected ducts.

D. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.

1. Minimum Weight: 26 oz./sq. yd. (880 g/sq. m).
2. Tensile Strength: 480 lbf/inch (84 N/mm) in the warp and 360 lbf/inch (63 N/mm) in the filling.
3. Service Temperature: Minus 40 to plus 200 deg F (Minus 40 to plus 93 deg C).

2.10 FLEXIBLE DUCTS

A. Insulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire; fibrous-glass insulation; aluminized vapor-barrier film.

1. Pressure Rating: 4-inch wg (1000 Pa) positive and 0.5-inch wg (125 Pa) negative.
2. Maximum Air Velocity: 4000 fpm (20 m/s).
3. Temperature Range: Minus 20 to plus 175 deg F (Minus 29 to plus 79 deg C).
4. Insulation R-Value: 8.0

B. Flexible Duct Connectors:

1. Clamps: Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action in sizes 3 through 18 inches (75 through 460 mm), to suit duct size.

2.11 DUCT ACCESSORY HARDWARE

A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel ducts.

C. Install control dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.

D. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts.

1. Install steel volume dampers in steel ducts.

E. Set dampers to fully open position before testing, adjusting, and balancing.

F. Install test holes at fan inlets and outlets and elsewhere as indicated.

G. Install fire dampers according to UL listing.

H. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:
1. At outdoor-air intakes and mixed-air plenums.
2. Downstream from manual volume dampers, control dampers, and equipment.
3. Adjacent to and close enough to fire dampers, to reset or reinstall fusible links. Access doors for access to fire dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
4. Control devices requiring inspection.
5. Downstream of terminal units with reheat coils.
6. Elsewhere as indicated.

I. Install access doors with swing against duct static pressure.

J. Access Door Sizes:
1. Two-Hand Access: 12 by 6 inches (300 by 150 mm).

K. Label access doors according to Division 23 Section "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.

L. Install flexible connectors to connect ducts to equipment.

M. Connect terminal units to supply ducts directly or with maximum 24 inch lengths of flexible duct. Do not use flexible ducts to change directions.

N. Connect diffusers to ducts directly or with maximum 720-inch (1500-mm) lengths of flexible duct clamped or strapped in place.

O. Connect flexible ducts to metal ducts with draw bands .

P. Install duct test holes where required for testing and balancing purposes.

3.2 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Operate fire dampers to verify full range of movement and verify that proper heat-response device is installed.
4. Inspect turning vanes for proper and secure installation.

END OF SECTION 233300

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SECTION 233600 - AIR TERMINAL UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Shutoff, single-duct air terminal units.

1.3 PERFORMANCE REQUIREMENTS

A. Structural Performance: Hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" .

1.4 SUBMITTALS

A. Product Data: For each type of the following products, including rated capacities, furnished specialties, sound-power ratings, and accessories.

1. Air terminal units.
2. Liners and adhesives.
3. Sealants and gaskets.

1.5 First paragraphQUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2004, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

PART 2 - PRODUCTS

2.1 SHUTOFF, SINGLE-DUCT AIR TERMINAL UNITS

A. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.

B. Casing: 0.034-inch (0.85-mm) steel , single wall.

1. Casing Lining: Adhesive attached, 1-inch thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

a. Cover liner with nonporous foil.

2. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
3. Air Outlet: S-slip and drive connections.
4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

C. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

1. Maximum Damper Leakage: ARI 880 rated, 2 percent of nominal airflow at 3-inch wg inlet static pressure.

D. Damper Position: Normally open.

A. Velocity Sensors: Center averaging, multipoint array

E. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.

F. Direct Digital Controls: Single-package unitary controller and actuator specified in Division 23 Section "Instrumentation and Control for HVAC" and provided to terminal unit manufacturer for factory installation.

2.2 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.

B. Steel Cables: Galvanized steel complying with ASTM A 603.

C. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

D. Air Terminal Unit Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

E. Trapeze and Riser Supports: Steel shapes and plates for units with steel casings; aluminum for units with aluminum casings.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."

B. Install air terminal units level and plumb. Maintain sufficient clearance for normal service and maintenance.

3.2 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes and for slabs more than 4 inches (100 mm) thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes and for slabs less than 4 inches (100 mm) thick.

C. Hangers Exposed to View: Threaded rod and angle or channel supports.

D. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.3 CONNECTIONS

A. Install piping adjacent to air terminal unit to allow service and maintenance.

B. Connect ducts to air terminal units according to Division 23 Section "Metal Ducts."

C. Make connections to air terminal units with flexible connectors complying with requirements in Division 23 Section "Air Duct Accessories."

3.4 IDENTIFICATION

A. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Division 23 Section "Identification for HVAC Piping and Equipment" for equipment labels and warning signs and labels.

3.5 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain air terminal units.

END OF SECTION 233600

SECTION 233713 - DIFFUSERS, REGISTERS, AND GRILLES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

1. This Section includes ceiling- diffusers, **r**egisters, and grilles.

B. Related Sections include the following:

1. Division 23 Section "Air Duct Accessories" for fire dampers and volume-control dampers not integral to diffusers, registers, and grilles.

1.3 SUBMITTALS

A. Product Data: For each product indicated, include the following:

1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.

PART 2 - Retain first paragraph and subparagraphsPRODUCTS

1.1 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

1. Approved Manufacturers: Subject to compliance with requirements, provide products comparable to one of the following:

a. Carnes.
b. Price Industries.
c. Titus.

1.2 GRILLES AND REGISTERS

A. Fixed Face Grille:

1. Basis-of-Design: Subject to compliance with requirements provide Titus; 355FL.
2. Material: Aluminum; except provide steel in fire rated ceilings.
3. Finish: Baked enamel, white.

4. Face Arrangement: 35 degree louvered blades, 1/2" spacing.
5. Frame: 1 inch 25 mm wide.
6. Mounting Frame: Provide 1" filter frame where indicated on plans.
7. Mounting: Countersunk screw or Lay in as required by ceiling type.

1.3 CEILING DIFFUSER OUTLETS

A. Square Plaque Ceiling Diffusers

1. Basis-of-Design: Subject to compliance with requirements provide Titus; OMNI-AA.
2. Material: Aluminum; except provide steel in fire rated ceilings.
3. Finish: Baked enamel, white
4. Face Style: Plaque

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas where diffusers, registers, and grilles are to be installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install diffusers, registers, and grilles level and plumb.

B. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practicable. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

C. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3 ADJUSTING

A. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 233713

SECTION 234100 - PARTICULATE AIR FILTRATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:

1. Pleated panel filters.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.

1.4 QUALITY ASSURANCE

A. ASHRAE Compliance:

1. Comply with applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality"; Section 5 - "Systems and Equipment"; and Section 7 - "Construction and Startup."
2. Comply with ASHRAE 52.1 for arrestance and ASHRAE 52.2 for MERV for methods of testing and rating air-filter units.

B. Comply with NFPA 90A and NFPA 90B.

PART 2 - PRODUCTS

2.1 PLEATED PANEL FILTERS

A. Description: Factory-fabricated, self-supported, extended-surface, pleated, panel-type, disposable air filters with holding frames.

1. Basis-of-Design Product: Subject to compliance with requirements, provide Camfil Farr**;** AP-Thirteen or comparable product by one of the following:

a. AAF International.

b. Airguard.
c. Flanders-Precisionaire.
d. Purafil, Inc.

B. Filter Unit Class: UL 900, Class 2.

C. Media: Synthetic fibers.

1. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
3. Media shall be coated with an antimicrobial agent.
4. Separators shall be bonded to the media to maintain pleat configuration.
5. Welded wire grid shall be on downstream side to maintain pleat.
6. Media shall be bonded to frame to prevent air bypass.
7. Support members on upstream and downstream sides to maintain pleat spacing.

D. Filter-Media Frame: Cardboard frame sealed or bonded to the media.

E. Capacities and Characteristics:

1. Initial Resistance: 0.41 **inch wg (102.5 Pa)** for 2" for 4"**(87.2 Pa)** at **500 fpm (2.5 m/s)**.
2. MERV Rating: 13 when tested according to ASHRAE 52.2.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.

B. Install filters in position to prevent passage of unfiltered air.

C. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing with new, clean filters.

D. Coordinate filter installations with duct and air-handling-unit installations.

3.2 CLEANING

A. After completing system installation and testing, adjusting, and balancing of air-handling and air-distribution systems, clean filter housings and install new filter media.

END OF SECTION 234100

SECTION 237313 - MODULAR INDOOR CENTRAL-STATION AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 PERFORMANCE REQUIREMENTS

A. Structural Performance: Casing panels shall be self-supporting and capable of withstanding 133 percent of internal static pressures indicated, without panel joints exceeding a deflection of **L/200** where "L" is the unsupported span length within completed casings.

1.3 ACTION SUBMITTALS

A. Product Data: For each air-handling unit indicated.

1. Unit dimensions and weight.
2. Cabinet material, metal thickness, finishes, insulation, and accessories.
3. Fans:

    a. Certified fan-performance curves with system operating conditions indicated.
    b. Certified fan-sound power ratings.
    c. Fan construction and accessories.
    d. Motor ratings, electrical characteristics, and motor accessories.

4. Certified coil-performance ratings with system operating conditions indicated.
5. Dampers, including housings, linkages, and operators.
6. Filters with performance characteristics.

1.4 INFORMATIONAL SUBMITTALS

A. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
   1. Fan Belts: **One** set(s) for each air-handling unit fan.

1.7 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.

C. ARI Certification: Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.

D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

E. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

F. Comply with NFPA 70.

1.8 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

B. Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

1.9 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, **provide products by one of the following**:
   1. Carrier Corporation; a member of the United Technologies Corporation Family.
   2. McQuay International
   3. Trane; American Standard Inc.
   4. AAON, Inc.

1.10 UNIT CASINGS

A. General Fabrication Requirements for Casings:

   1. Frame: Welded, 14-gauge tubular carbon steel painted with a lacquer resisting phenolic corrosion inhibitive primer.

2. Thermal Break: Casing shall be "no-through-metal" design. The casing structure shall incorporate insulating thermal breaks so no path exists of continuous unbroken metal to metal conduction from inner to outer surfaces. Panels shall be removable without affecting the structural integrity of the unit. If manufacturer cannot provide thermal break or removable panels it must be noted as an exception on bid.

1. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
2. Casing Joints: Sheet metal screws or pop rivets.
3. Sealing: Seal all joints with water-resistant sealant.
4. Exterior Casing Coating for Galvanized-Steel Casings: **Synthetic resin** Color shall be manufacturer's standard.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

B. Casing Insulation:

1. Location and Application: Encased between outside and inside casing.

C. Inspection and Access Panels and Access Doors:

1. Panel and Door Fabrication: Formed and reinforced, double-wall and insulated panels of same materials and thicknesses as casing. Door frame shall have built in thermal break barrier and full perimeter gasket; if manufacturer cannot provide thermal break door design it shall be noted as an exception in the bid.

2. Access Doors:

a. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside and outside. Arrange doors to be opened against air-pressure differential.
b. Gasket: Neoprene, applied around entire perimeters of panel frames.
c. Size: At least **12 inches (600 mm)** wide by full height of unit casing up to a maximum height of **60 inches (1500 mm)**.

3. Locations and Applications:

a. Fan Section: **Doors**.
b. Access Section: Doors.
c. Damper Section: **Doors**.
d. Filter Section: **Doors** large enough to allow periodic removal and installation of filters.
e. Mixing Section: Doors.

D. Condensate Drain Pans:

1. Fabricated with **two** percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and from humidifiers and to direct water toward drain connection.

a. Length: Extend drain pan downstream from leaving face **to comply with ASHRAE 62.1**.
b. Depth: A minimum of **2 inches (50 mm)** deep.

2. **Formed sections**.
3. Double-wall, **stainless**-steel sheet with space between walls filled with foam insulation and moisture-tight seal. Insulation shall be minimum 2-inch thick.
4. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on **one end** of pan. Drain connection centerline shall be a minimum of 2-inches above mounting frame.

    a. Minimum Connection Size: **NPS 1 (DN 25)** .

E. Air-Handling-Unit Mounting Frame: Provide 8-inch high Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs. Base frame shall provide full perimeter support and cross support members at splits and as needed to support internal components. Base and unit frame shall be painted with a lacquer resisting phenolic corrosion inhibitive primer.

1.11 FAN, DRIVE, AND MOTOR SECTION

A. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.

1. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment.

    a. Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
    b. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

B. Plenum Fan Housings: Steel frame and panel; fabricated without fan scroll and volute housing.

C. Fan Shaft Bearings:
1. Grease-Lubricated, Tapered-Roller Bearings: Self-aligning, pillow-block type with double-locking collars and 2-piece, cast-iron housing with grease lines extended to outside unit and a rated L50 life of 200,000 hours according to FABMA 11.

D. Belt Drives: Factory mounted, with adjustable alignment and belt tensioning, and with 1.5 service factor based on fan motor. Minimum of 2 belts shall be provided on all fans with 10 hp and larger motors.

1. Pulleys: Cast iron or cast steel with split tapered bushing; dynamically balanced at factory.
2. Motor Pulleys: Adjustable pitch for use with **5** -hp motors and smaller; fixed pitch for use with motors larger than **5** hp. Select pulley size so pitch adjustment is at the middle of adjustment range at fan design conditions.
3. Belts: Oil resistant, nonsparking, and nonstatic; in matched sets for multiple-belt drives.

E. Internal Vibration Isolation : Fans shall be factory mounted with manufacturer's standard double deflection, neoprene mount vibration isolation mounting devices.

F. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements for HVAC Equipment."

1. Enclosure Type: Open drip proof.
2. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.
3. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
4. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.

1.12 COIL SECTION

A. General Requirements for Coil Section:

1. Comply with ARI 410.
2. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
3. Coils shall not act as structural component of unit.

1.13 AIR FILTRATION SECTION

A. General Requirements for Air Filtration Section:

1. Comply with NFPA 90A.
2. Provide filter holding frames arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.

B. Filter Gage:

1. 3-1/2-inch- (90-mm-) diameter, diaphragm-actuated dial in metal case.
2. Vent valves.
3. Black figures on white background.
4. Front recalibration adjustment.
5. 2 percent of full-scale accuracy.
6. Range: 0- to 2.0-inch wg (0 to 500 Pa).
7. Accessories: Static-pressure tips with integral compression fittings, 1/4-inch (6-mm) aluminum tubing, and 2- or 3-way vent valves.

1.14 DAMPERS

A. General Requirements for Dampers: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed 2 percent of air quantity at 2000-fpm (10-m/s) face velocity through damper and 4-inch wg (1000-Pa) pressure differential.

B. Damper Operators: Comply with requirements in Division 23 Section "Instrumentation and Control for HVAC."

C. Outdoor- and Return-Air Dampers: Low-leakage, double-skin, airfoil-blade, galvanized-steel dampers with compressible jamb seals and extruded-vinyl blade edge seals in opposed -blade arrangement with cadmium-plated steel operating rods rotating in stainless-steel sleeve bearings mounted in a single galvanized-steel frame, and with operating rods connected with a common linkage. Leakage rate shall not exceed 5 cfm/sq. ft. (0.22 L/s per sq. m) at 1-inch wg (250 Pa) and 9 cfm/sq. ft. (0.4 L/s per sq. m) at 4-inch wg (1.0 MPa).

D. Outside Air Monitor: Factory installed outside air monitoring station. Design air monitoring station to handle maximum and minimum air flow rates. Provide a complete package to allow for connection to BAS control system. Trane Traq Damper or approved equal.

1.15 CAPACITIES AND CHARACTERISTICS

A. Casing:

1. Outside Casing: 90g Galvanized steel, minimum **0.064 inch (1.6 mm)** thick.
2. Inside Casing: 90g Galvanized steel, **solid** for all sections
3. Base Floor Plate: 90g Galvanized steel, minimum **0.064 inch (1.6 mm)** thick.
4. Base Outside Casing: G90 galvanized steel, minimum 0.040 inch thick.Insulation Thickness: Minimum **2 inches (50 mm)**>.
5. Static-Pressure Classifications for Unit Sections before Fans: **6-inch wg (1500 Pa)**.
6. Static-Pressure Classifications for Unit Sections after Fans: **6-inch wg (1500 Pa)**.

B. Supply Fan:

1. **Class II** : AMCA 99-2408.
2. Drive: **V-belt**.
3. Type: **Steel, airfoil centrifugal**.
4. Fan Housing and Wheel Coating: **Synthetic resin**.

C. Cooling Coil:

1. Maximum Face Velocity: 500 **fpm**.
2. Maximum Air-Side, Static-Pressure Drop: 1.0 **inches wg (Pa)**.
3. Coil Type: **Self-draining**.
4. Piping Connections: **Threaded**, **same end** of coil.
5. Tube Material: **Copper**.
6. Tube Thickness: 0.25**inches** .
7. Fin Type: **Plate**.
8. Fin Material: **Aluminum**.
9. Maximum Fin Spacing: 10 **inch**.
10. Fin Thickness: **0.01 inches**.
11. Fin and Tube Joint: **Mechanical bond**.
12. Seamless copper tube with brazed joints, prime coated.Headers:
13. Frames: Channel frame, **0.0625-inch- (1.58-mm-) thick stainless steel**.
14. Maximum Number of Rows: 8.
15. Coil Working-Pressure Ratings: **200 psig (1380 kPa), 325 deg F (163 deg C)**.

1.16 SOURCE QUALITY CONTROL

A. Fan Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.

B. Fan Performance Rating: Factory test fan performance for airflow, pressure, power, air density, rotation speed, and efficiency. Rate performance according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating."

C. Water Coils: Factory tested to 300 psig (2070 kPa) according to ARI 410 and ASHRAE 33.

PART 2 - EXECUTION

2.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine casing insulation materials and filter media before air-handling unit installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for hydronic, and condensate drainage piping systems and electrical services to verify actual locations of connections before installation.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

2.2 INSTALLATION

A. Equipment Mounting: Install air-handling units on concrete bases **using restrained spring isolators**. Secure units to anchor bolts installed in concrete bases. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."

1. Minimum Deflection: **2 inches (50 mm)**.
2. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
3. Install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
4. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
5. Install anchor bolts to elevations required for proper attachment to supported equipment.

B. Arrange installation of units to provide access space around air-handling units for service and maintenance.

C. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.

D. Install filter-gage, static-pressure taps upstream and downstream of filters. Mount filter gages on outside of filter housing or filter plenum in accessible position. Provide filter gages on filter banks, installed with separate static-pressure taps upstream and downstream of filters.

2.3 CONNECTIONS

A. Comply with requirements for piping specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to air-handling unit to allow service and maintenance.

C. Connect piping to air-handling units mounted on vibration isolators with flexible connectors.

D. Connect condensate drain pans using NPS 1-1/4 (DN 32), ASTM B 88, Type M (ASTM B 88M, Type C) copper tubing. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

E. Hot- and Chilled-Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping." Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.

F. Connect duct to air-handling units with flexible connections. Comply with requirements in Division 23 Section "Air Duct Accessories."

2.4 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:

1. Leak Test: After installation, fill water and steam coils with water, and test coils and connections for leaks.
2. Charge refrigerant coils with refrigerant and test for leaks.
3. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

D. Prepare test and inspection reports.

2.5 STARTUP SERVICE

A. Perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that shipping, blocking, and bracing are removed.
3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
6. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
7. Comb coil fins for parallel orientation.
8. Install new, clean filters.
9. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

B. Starting procedures for air-handling units include the following:

1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm. Replace fan and motor pulleys as required to achieve design conditions.
2. Measure and record motor electrical values for voltage and amperage.
3. Manually operate dampers from fully closed to fully open position and record fan performance.

2.6 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Division 23 Section "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

2.7 CLEANING

A. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

2.8 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

END OF SECTION 237313