SECTION 23 01 00 – HVAC GENERAL WORK REQUIREMENTS

PART 1 - GENERAL

1.1. SUMMARY

A. This section includes general requirements and information for Division 23 work.

1.2. DEFINITIONS

A. Owner Acceptance for Beneficial Occupancy: Work that is judged by the Engineer to be substantially complete, accepted to be safe for use by the Authority Having Jurisdiction (AHJ), and accepted by the Owner. Acceptance comes with an agreement the Engineer's written punchlist of outstanding items will be completed to fulfill the contractual obligations.

B. Full Owner Occupancy: Owner will occupy the site and existing building during entire construction period.

C. Partial Owner Occupancy: Owner may occupy completed areas of building before Owner Acceptance.

D. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct chases, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.

E. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.

F. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

G. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and chases.

H. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.

I. Provide: Contractor shall furnish and install materials, equipment or fixtures as indicated.

J. Install Items Furnished by Owner or Others: Contractor shall receive shipment, store, install and verify materials, equipment or fixtures selected and purchased outside of the prime construction contract as indicated.

K. Furnish Items to Owner or Others: Contractor shall purchase and deliver materials, equipment or fixtures for installation by others as indicated.

1.3. SUBMITTALS

A. Qualification Submittals:

1. Welding certificates.

B. Product Submittals:

1. Wall and ceiling access door product information.

C. Construction Submittals:

1. Manufacturer startup, operation and maintenance checklists for all equipment and devices included in Division 23 specifications in a single submittal package for review prior to equipment startup.

D. Closeout Submittals:

1. Manufacturer startup, operation and maintenance reports with completed checklists signed by the involved technicians and the Mechanical Contractor's witnessing superintendent.

1.4. INSPECTIONS

A. Contractor shall be responsible for obtaining all inspections from regulatory agencies having jurisdiction over the project. These inspections include but are not limited to: VA Department of Labor and Industry (VADOLI) – Boiler Safety Bureau for boilers and pressure vessels, VA Department of Education, and other State inspection authorities as applicable.

1.5. QUALITY ASSURANCE

A. Welding Qualifications:

1. Installer Qualifications: Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.
2. AWS D1.1, "Structural Welding Code--Steel."
3. AWS D1.2, "Structural Welding Code--Aluminum."
4. AWS D1.3, "Structural Welding Code--Sheet Steel."
5. AWS D1.4, "Structural Welding Code--Reinforcing Steel."
6. ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."

B. Roof Warranties: All work on roofs shall comply with the roof manufacturer's warranty requirements. For work on existing roofs, obtain a copy of the owner's roof warranty prior to the start of work.

C. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

D. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

1.6. WARRANTY

A. Project Warranty: All work performed and all materials installed in Division 23 shall be warrantied by the Contractor for 1 year from the Owner's written acceptance of Owner Acceptance. The warranty shall include all labor and parts. The Contractor shall be on site within 48 hours of Owner notifications.

1. This warranty does not waive the Owner's obligation to provide routine maintenance. Routine maintenance includes maintenance recommended by each equipment manufacturer and industry standard requirements for overall systems as documented in the project's Operation and Maintenance Manuals. Replacement of wear items such as filters, belts, etc. are not included in the warranty unless they are incidental to other warranty work being performed. Failures due to the lack of routine maintenance are the responsibility of the Owner.

2. Equipment manufacturer's disclaimers and limitations on product warranties do not relieve the Contractor of the obligations of the Project Warranty.

3. Extended or special warranties defined in other sections shall be in addition to, and run concurrently with, the Project Warranty.

1.7. PROJECT DOCUMENTS

A. Project Documents: Division 23 project documents are diagrammatic in nature and intended to represent complete and functioning systems. If any aspect of the work is undefined or unclear, submit your questions in writing prior to the final addendum deadline as defined in the specifications and/or at the pre-bid conference. If any aspect of the work is undefined or unclear after the final addendum, include the cost for the highest quality solution. The contractor is encouraged to thoroughly review the contract documents and site conditions prior to bidding.

B. Basis of Design Manufacturers: Manufacturer names and model numbers of equipment and devices noted on drawings and in equipment schedules shall be considered the Engineer's basis of design. Proposed changes to the basis of design shall be submitted to the Engineer for review and approval. The submittal shall include a description of all changes necessary to implement the substitution, including but not limited to plumbing, mechanical and electrical connections; dimensions, weights and structural supporting structure; layout changes necessary to maintain clearances; and acoustical treatments. All changes required to implement a substitution is the responsibility of Contractor at no added cost to the Owner.

C. Listed Manufacturers: Manufacturers listed in the Division 23 specification sections and on drawings must meet all the requirements of the project documents. <u>Listed manufacturers that do not meet the requirements will not be accepted</u>. The manufacturer listing does not result in an automatic approval. In addition to construction and performance requirements, the proposed equipment must meet the indicated physical dimension, weight, acoustic, power, controls, and plumbing limitations of the project. Verify existing conditions in the field, when applicable, and proposed conditions prior to submitting equipment for Engineer review. When full project coordination drawings are not required, generate coordination drawings to the level of detail necessary to determine if the proposed equipment will comply with the project documents and manufacturer recommended maintenance clearances.

1. If a manufacturer's equipment does not meet the physical dimension, weight, acoustic, power, controls and plumbing limitations of the project, a change order proposal may be submitted for the Owner's and Engineer's consideration. The proposal shall include all changes, including other trades, required and a reduction in cost to accept the non-

conforming equipment. The base bid shall include equipment that fully meets the design requirements at no additional cost.

1.8. COMMISSIONING PROCESS

A. General: The Owner's Commissioning Agent (CxA) will lead a commissioning team made up of owner and contractor representatives. Refer to Section 019113 for more information.

1. Members Appointed by Contractor(s): Individuals, each having the authority to act on behalf of the entity he or she represents, explicitly organized to implement the commissioning process through coordinated action. The commissioning team shall consist of, but not be limited to, representatives of each Contractor, including Project superintendent and subcontractors, installers, suppliers, and specialists deemed appropriate by the CxA.
2. Owner's CxA: The designated person, company, or entity that plans, schedules, and coordinates the commissioning team to implement the commissioning process. Owner will engage the CxA under a separate contract.
3. Owner's Facility Representatives: Facility user and operation and maintenance personnel.
4. Engineers: Design professional.

B. Contractor's Responsibilities:

1. Each Contractor shall assign representatives with expertise and authority to act on its behalf and shall schedule them to participate in and perform commissioning process activities including, but not limited to, the following:
   a. Evaluate performance deficiencies identified in test reports and, in collaboration with entity responsible for system and equipment installation, recommend corrective action.
   b. Cooperate with the CxA for resolution of issues recorded in the Issues Log.
   c. Attend commissioning team meetings held on a weekly basis.
   d. Integrate and coordinate commissioning process activities with construction schedule.
   e. Review and accept construction checklists provided by the CxA.
   f. Complete construction checklists as Work is completed and provide to the Commissioning Authority on a weekly basis.
   g. Review and accept commissioning process test procedures provided by the Commissioning Authority.
   h. Complete commissioning process test procedures.

C. CxA's Responsibilities:

1. Organize and lead the commissioning team.
2. Provide commissioning plan.

3. Convene commissioning team meetings.

4. Provide Project-specific construction checklists and commissioning process test procedures.

5. Verify the execution of commissioning process activities using random sampling. The sampling rate may vary from 1 to 100 percent. Verification will include, but is not limited to, equipment submittals, construction checklists, training, operating and maintenance data, tests, and test reports to verify compliance with the OPR. When a random sample does not meet the requirement, the CxA will report the failure in the Issues Log.

6. Prepare and maintain the Issues Log.

7. Prepare and maintain completed construction checklist log.

8. Witness systems, assemblies, equipment, and component startup.

9. Compile test data, inspection reports, and certificates; include them in the systems manual and commissioning process report.

1.9. COORDINATION

A. Maintenance Access: Install equipment and devices in such a manner to be readily accessible for testing, adjusting, balancing, inspection and maintenance. All concealed equipment and devices, including but not limited to equipment, valves, dampers, actuators, sensors, gauges, test ports, filter housings, coils, etc., shall be installed above accessible ceilings, within accessible rooms or chases or within normally inaccessible construction with access doors. All access doors are not shown in the project drawings. All access doors shall be coordinated with the Engineer prior to the installation of the equipment or device. Equipment and/or devices not coordinated prior to installation, as judged by the Engineer, shall be removed and reinstalled at no added cost.

B. Arrange for pipe spaces, chases, slots, and openings in building structure during progress of construction, to allow for HVAC installations.

C. Coordinate installation of required supporting devices and set sleeves in poured-in-place concrete and other structural components as they are constructed.

D. Coordinate requirements for access panels and doors for HVAC items requiring access that are concealed behind finished surfaces.

1.10. SPECIAL TESTS AND INSPECTIONS

A. Special Tests and Inspections: Owner will engage a qualified Special Inspector to conduct special tests and inspections required by authorities having jurisdiction as the responsibility of Owner as indicated in the Statement of Special Inspections.

B. Special Inspector: The Special Inspector’s scope of work will be defined by the Owner. In general they will verify the materials have been installed properly and completely; notify the Owner, Engineer and Contractor of deficiencies; test corrected work, and submit a certified report of their procedures and findings.

1. Coordinate observations and testing with the Special Inspector and correct noted deficiencies.

C. Mechanical System Special Inspections:

1. Seismic resistance components in Section 230548.
2. Wind resistance components in Section 230548.
3. Firestopping systems in Section 230500.
4. Smoke controls systems.

1.11. VOC CONTENTS

A. Low Volatile Organic Compounds (VOC) Requirements: All adhesives, mastics, sealants and compounds factory or field applied that are installed indoors and all paint field applied shall be certified as low VOC content when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

1. Adhesives: 50 g/L or less, except 80 g/L or less for calcium silicate and mineral fiber insulation and 30 g/L or less for metal-to-metal adhesives.
2. Mastics: 50 g/L or less.
3. Sealants: 250 g/L or less for duct sealants and 420 g/L or less for equipment insulation joint sealants.
4. Compounds: 490 g/L or less for CPVC welding compounds and 510 g/L or less for PVC welding compounds.
5. Paints: 50 g/L or less for flat paints and primers and 150 g/L or less for non-flat paints.

PART 2 - PRODUCTS

2.1. PAINTS AND PRIMERS

A. General: Provide primers and paints designed for the intended applications. All primers and paints used indoors shall be low-odor and low VOC content type.

B. Primers:

1. Metal Applications: Water-based rust-inhibitive primer.
2. Aluminum Applications: Quick-drying primer for aluminum.
3. Wood Applications: Latex-based wood primer.
4. Interior Applications: Interior latex primer/sealer.

C. Paints:

1. Interior Applications: High-performance interior latex.
2. Exterior Applications: Exterior latex.

3. Match gloss level to adjacent finishes when applicable. Flat gloss level for all other applications, unless otherwise indicated.

2.2. CONCRETE MATERIALS

A. Concrete: Use the following unless otherwise indicated:

1. Equipment Housekeeping Pads: Light-weight aggregate with 3000 psi, 28-day minimum compressive strength.

2. Miscellaneous Uses: Medium-weight aggregate with 4000 psi, 28-day minimum compressive strength.

B. Reinforcing Bars: ASTM A 615/A 615M, Grade 60, deformed.

C. Welded Wire Steel Reinforcement: ASTM A 185, fabricated from as-drawn steel wire into flat sheets.

2.3. GROUT

A. Description: ASTM C 1107, Grade B, non-shrink and nonmetallic, dry hydraulic-cement grout.

B. Characteristics: Post-hardening, volume-adjusting, non-staining, noncorrosive, nongaseous, and recommended for interior and exterior applications.

C. Design Mix: 5000-psi, 28-day compressive strength.

D. Packaging: Premixed and factory packaged.

2.4. PATCHING MATERIALS

A. General: Comply with requirements specified in other Sections.

B. In-Place Materials: Use materials identical to in-place materials. For exposed surfaces, use materials that visually match in-place adjacent surfaces to the fullest extent possible.

1. If identical materials are unavailable or cannot be used, use materials that, when installed, will match the visual and functional performance of in-place materials.

2.5. ESCUTCHEONS AND FLOOR PLATES

A. Escutcheons:

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

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

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

B. Floor Plates:

1. One-Piece Floor Plates: Cast-iron flange with holes for fasteners.

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

2.6. ACCESS DOORS AND FRAMES, WALLS AND CEILINGS

A. Flush Access Doors with Concealed Flanges: Sheet steel door and frame, minimum 16-gauge, with face of door flush with frame, concealed flange and hinge, and key-operated lock and latch bolt.

1. Finish: Factory-painted flat white for white ceiling and wall surfaces. Factory-primed for field painted surfaces.

2. Coordinate frame styles with ceiling and wall types.

3. Fire and Smoke-Rated Access Doors and Frames: Access doors located within fire and smoke-rated walls and ceilings shall be self-closing, listed and labelled by a qualified testing agency and comply with NFPA 80. Ratings shall meet or exceed the rating of the adjacent construction.

PART 3 - EXECUTION

3.1. DOCUMENTATION OF PROJECT CONDITIONS

A. Project Conditions: Document in digital-format photos and video the existing project conditions and continue to document the conditions as the project progresses. Owner claims of contractor damage will be judged by the documented conditions.

3.2. OPERATION AND MAINTENANCE MANUALS

A. The contractors shall deliver one complete set of bookmarked manuals in electronic PDF format of all operation and maintenance manuals to the Owner through the Designer, two (2) weeks before the pre-final inspection is held. The manuals shall be bookmarked to a minimum of one level – ie: each major piece of equipment (chiller, boiler switchboard, water closet, water heater, etc.) or document category (warranties, parts list, contact information, etc.) The manuals shall be delivered by one of the following:

1. USB Drive

2. CD/DVD

3. Downloadable file from FTP Site

B. Manuals shall include the following (at a minimum):

1. Index and page numbers

2. Certificate of Owner Acceptance

3. Summary sheet of warranties with dates noted and a copy of all warranties

4. List of all subcontractors and suppliers with names, addresses, and phone numbers

5. Special Inspection Reports

6. Certified Test and Balance Report
7. Complete start-up, operation, and shutdown procedures for each system including sequence of events, locations of switches, emergency procedures, and any other critical items.
8. Lubrication schedules and types of lubricants
9. Complete set of all submittal data and current shop drawings (including 3rd party generated shop drawings) and equipment description showing all capacities and other operation conditions.
10. Equipment summary showing all capacities and ratings (HP, Tons, kW, filter size, etc.).

3.3. OPERATION OF HVAC SYSTEMS DURING CONSTRUCTION

A. The Prime Contractor shall provide temporary heating, ventilation and air-conditioning as needed for the construction process. Use of the permanent HVAC is prohibited.

B. Permanent HVAC systems and components may only be operated for verification, testing, adjusting and balancing.

C. Owner/Engineer shall approve project conditions prior to system start-ups. Request start-up inspection minimum of 2 weeks prior to proposed start. Proposed start shall be coordinated with Owner's/Engineer's schedule.

D. Air System Temporary Operation: Systems shall only be operated when the building is completely enclosed, is clean and there are no dust or fume creating activities being performed.

1. Filtration: Prior to starting air systems, verify clean filters are installed in all air system equipment and clean temporary filter media is installed on all air intakes. Replace temporary filters on a regular basis. Provide minimum MERV-8 temporary filter media and comply with Section 234100. Replace all filters with new prior to Owner acceptance.
2. Air System Equipment Cleaning: Clean inside of air system equipment and install filters.
3. Air Handling Unit Control: The goal of construction conditioning is to remove excessive humidity to allow the installation of finishes. It is not to meet building design temperature.

   a. Air handlers should be started initially at 100-percent outside air. Outside air intakes shall have a double layer of blue roll filter media, either at the outside air intake louvers or directly inside the unit prior to prefilters. If outside air intakes are going to be exposed to dust and dirt from site construction, consideration should be made to temporarily relocate intake by ducting to an elevation where the intake is protected from dirt and dust. Roll filter media should be periodically monitored for build-up and replaced as necessary. Do not operate unit while changing filters.

   b. If systems do not have 100-percent outside air capability and return duct must be utilized, all return openings must be filtered to prevent contaminating the duct system and equipment.

c. When using return air, do not close outside air damper completely. Balance outside air flow to 10 to 20-percent of total flow to maintain positive pressure in the building.

E. Hydronic System Temporary Operation: Systems shall only be operated when the spaces where pumps, motors and variable speed drives are located are clean and there are no dust or fume creating activities being performed.

1. Cleaning: Prior to starting hydronic systems, verify motor housings are clean by using compressed air to blow out any dust and debris. Clean them on a regular basis during system operation.

F. Owner/Engineer must approve operation of the permanent HVAC systems for use at Owner Acceptance.

3.4. WELDING AND BRAZING

A. Medium and High Pressure Piping (Above 15 psig):

1. Fabrication:

a. Medium and high pressure steam and heating water piping systems shall be fabricated, assembled and welded in accordance with ASME B31.1, and Power Piping Codes PFI ES 1, PFI ES 3, PFI ES 7, PFI ES 21, PFI ES 31, PFI ES 35, and PFI TB1 of the Piping Fabrication Institute's companion code requirements.

b. Other high pressure piping systems shall be fabricated, assembled and welded/brazed/ soldered in accordance with ASME B31.3, and Power Piping Codes PFI ES 1, PFI ES 3, PFI ES 7, PFI ES 21, PFI ES 31, PFI ES 35, and PFI TB1 of the Piping Fabrication Institute's companion code requirements.

c. Refrigeration piping systems shall be fabricated, assembled and welded/brazed in accordance with the ASME B31.5.

2. Non-Destructive Inspection and Testing: All pipe welds shall be tested by a qualified, Engineer approved, testing agency at the expense of the contractor.

B. Low Pressure Piping (15 psig and lower):

1. Fabrication:

a. Copper make-up water and drainage piping systems shall be fabricated, assembled and soldered in accordance with ASTM B828.

b. Other low pressure piping systems shall be fabricated, assembled and welded/brazed in accordance with the ASME B31.9.

3.5. PAINTING

A. Comply with manufacturer's written instructions and recommendations in "MPI Architectural Painting Specification Manual" applicable to substrates indicated.

B. Clean substrates of substances that could impair bond of paints, including dirt, oil, grease, and incompatible paints and encapsulants.

1. Remove incompatible primers and re-prime substrate with compatible primers as required to produce paint systems indicated.

C. Apply paints to produce surface films without cloudiness, spotting, holidays, laps, brush marks, roller tracking, runs, sags, ropiness, or other surface imperfections. Cut in sharp lines and color breaks.

D. Painting of Division 23 Work: Paint items exposed in equipment rooms and occupied spaces including, but not limited to, the following:

1. Visible portions of internal surfaces of metal ducts, without liner, behind air inlets and outlets.

2. Duct, equipment, and pipe insulation having cotton, canvas or metal insulation covering or other paintable jacket material as required by Section 230553 and elsewhere as indicated.

3. Mechanical equipment that is indicated to have a factory-primed finish for field painting.

E. Protect work of other trades against damage from paint application. Correct damage to work of other trades by cleaning, repairing, replacing, and refinishing, as approved by Engineer, and leave in an undamaged condition.

F. At completion of construction activities of other trades, touch up and restore damaged or defaced painted surfaces. Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.

3.6. CONCRETE

A. Design, construct, erect, brace, and maintain formwork according to ACI 301.

B. Comply with CRSI's "Manual of Standard Practice" for fabricating, placing, and supporting reinforcement.

C. Comply with ACI 301 for measuring, batching, mixing, transporting, and placing concrete.

D. Equipment Concrete Bases: Housekeeping pads shall match the indicated dimensions but not be less than required to extend 4-inches beyond the equipment footprint in each direction and have chamfered edges.

1. Concrete Base Depths:

a. Air Handling Units: Minimum 6-inches thick, unless otherwise indicated.

b. HVAC Equipment: Minimum 4-inches thick, unless otherwise indicated.

2. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of the base.

3. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.

4. Place and secure anchorage devices. Use supported equipment manufacturer's 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.

6. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

3.7. GROUTING

A. Mix and install grout for HVAC equipment base bearing surfaces, pump and other equipment base plates, and anchors.

B. Clean surfaces that will come into contact with grout.

C. Provide forms as required for placement of grout.

D. Avoid air entrapment during placement of grout.

E. Place grout, completely filling equipment bases.

F. Place grout on concrete bases and provide smooth bearing surface for equipment.

G. Place grout around anchors.

H. Cure placed grout.

3.8. WALL, FLOOR AND ROOF OPENINGS

A. Exterior and interior wall, floor and roof openings made for duct, piping and conduit penetrations shall maintain the building's structural integrity. Install penetration sleeves, framing and lintels in accordance with the structural engineer.

3.9. REPAIR AND PATCHING

A. Repair damage created during the construction process. Repair quality shall be equal to or better than original condition as judged by the Architect/Engineer.

B. Patch wall, floor and roof openings created by removal of mechanical system items during the construction process. Patch and finish with materials consistent with adjacent finishes and materials.

1. Openings in fire /smoke rated assemblies shall be patched per UL-listed detail.

C. Identify and document existing building damage and openings in walls, floor and roof that are outside the project scope prior to the start of work. Report them promptly to the Architect/Engineer.

3.10. ACCESS DOOR INSTALLATION

A. Coordinate the need and exact location of each access door with Architect/Engineer prior to installation.

B. Center wall and ceiling access doors on duct access doors, valve centers, junction boxes, etc. to provide the best access to inspect, operate, and maintain the associated mechanical and electrical devices.

C. Install wall and ceiling access doors level and square to building surfaces. Comply with manufacturer's written instructions.

D. Install access doors such that their door swings are not blocked from opening fully and they open in the direction that provides the best access for the user.

E. Adjust doors and hardware for proper installation.

F. Touch-up door finishes with factory-provided paint as needed prior to completion.

G. Verify fire and smoke-rated door labels have not been painted over in the field.

H. Label wall and ceiling access doors with clear plastic ceiling tags in compliance with Section 23 05 53.

3.11. PIPING SYSTEM INSTALLATION GENERAL REQUIREMENTS

A. Install piping according to the following requirements and Division 23 Sections specifying piping systems.

B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

C. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.

D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

F. Install piping to permit valve servicing.

G. Install piping at indicated slopes.

H. Install piping free of sags and bends.

I. Install fittings for changes in direction and branch connections.

J. Install piping to allow application of insulation.

K. Select system components with pressure rating equal to or greater than system operating pressure.

L. Install sleeves for pipes passing through concrete and masonry walls, gypsum-board partitions, and concrete floor and roof slabs. Refer to Section 230517 for more information about sleeves and sleeve seals.

M. Verify final equipment locations for roughing-in.

N. Refer to equipment specifications in other Sections of these Specifications for roughing-in requirements.

O. Piping Connections: Make piping connections according to the following unless otherwise indicated:

1. Install unions, in piping 2-inches NPS and smaller, adjacent to each valve and at final connection to each piece of equipment.

2. Install flanges, in piping 2-1/2 inches NPS and larger, adjacent to flanged valves and at final connection to each piece of equipment.

3.12. ESCUTCHEONS AND FLOOR PLATES INSTALLATION

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

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

1. New Piping: Install one-piece cast-brass type for new piping installations. Install deep-pattern type where piping sleeve protrudes from the floor or wall.

2. Existing Piping: Install split-casting brass type for existing piping installations.

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

D. Install floor plates with inside diameter to closely fit around pipe, tube, and insulation of piping and with outside diameter that completely covers opening.

1. New Piping: One-piece, floor-plate type.

2. Existing Piping: Split-casting, floor-plate type.

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

3.13. EQUIPMENT INSTALLATION GENERAL REQUIREMENTS

A. Install equipment to allow maximum possible headroom unless specific mounting heights are not indicated.

B. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.

C. Install HVAC equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.

D. Install equipment to allow right of way for piping installed at required slope.

3.14. MECHANICAL SYSTEM MOCK-UPS

3.15. ADDITIONAL CONSTRUCTION PROCEDURES

A. General Requirements: In addition to the requirements of Division 1 and individual Division 23 sections, the Contractor shall comply with the following requirements during project construction:

1. Bidding: Review the requirements in the entire set of bid documents. Review the Project Documents paragraphs in Part 1 of this section. Submit clarification questions in compliance with Division 1 and Division 23.

2. Submittals: Submit delegated design, qualification, product, construction and close-out submittals required in each Division 23 section. Utilize the Submittal List in Section 230110 to verify each submittal has been submitted and reviewed prior to the installation of related equipment and materials.

3. Reference Documents: Maintain a hard copy set of Division 23 bid documents and submittals for reference in the on-site project office. Mark documents to record installed conditions and tested duct and piping.

    a. Duct and Pipe Pressure and Leakage Testing: Upon successful completion of testing each section of duct and pipe, number, highlight, date and initial the tested sections. The section numbers shall match in the testing report. Each tested section shall be initialed by an appropriate representative from the Contractor and Owner / Commissioning Agent or Engineer.

    b. Life-Safety Dampers: Successfully tested life-safety dampers shall be highlighted and initialed by an appropriate representative from the Contractor and Owner / Commissioning Agent or Engineer.

4. Stored Material Verification: In coordination with each monthly Owner Construction Coordination Meeting, provide a copy of the month's proposed Payment Application and access to all equipment or material stored in an off-site insured and bonded warehouse for verification meeting the requirements of Division 1. Payment Applications with unverified off-site stored equipment and materials will not be approved.

5. Pre-Installation and Testing Meetings: Schedule Pre-Installation Meetings required in Division 23 sections with the Owner / Commissioning Agent and Engineer.

6. Equipment Start-Up: Schedule major equipment start-up procedures with the Owner / Commissioning Agent and Engineer.

END OF SECTION

SECTION 23 02 00 – HVAC SYSTEMS OWNER TRAINING

PART 1 - GENERAL

1.1. SUMMARY

A. This section includes general requirements for the owner's demonstration and training of Division 23 systems and equipment.

1.2. SUBMITTALS

A. Construction Submittals:

1. Instruction Program: Submit outline of instructional program for demonstration and training including proposed dates, times, lengths of instruction times, instructor's name and instructor's qualifications.

B. Close-Out Submittals:

1. Training Attendance List.

2. Demonstration and Training Videos: Submit two copies within 14 days of the end of training program.

1.3. QUALITY INSURANCE

A. Facilitator Qualifications: A firm or individual experienced in training or educating maintenance personnel in a training program similar in content and extent to that indicated for this Project, and whose work has resulted in training or education with a record of successful learning performance.

B. Instructor Qualifications: A factory-authorized service representative experienced in operation and maintenance procedures and training.

C. Pre-Instruction Conference: Conduct conference at the project site. Review methods and procedures related to demonstration and training.

D. Coordinate content of training modules with content of approved emergency, operation, and maintenance manuals. Do not submit instruction program until operation and maintenance data has been reviewed and approved by Architect.

PART 2 - PRODUCTS

2.1. INSTRUCTION PROGRAM

A. Program Structure: Develop an instruction program that includes individual training modules for each system and equipment not part of a system, as required by individual Specification Sections, and as follows:

1. HVAC Control Systems

2. Flow and Energy Meters
3. Motor Starters and Disconnect Switches
4. Variable Speed Drives
5. Life-Safety Dampers
6. Fans, Supply, Return, Relief and Exhaust
7. Heaters including Unit Heaters, Finned-Tube and Convectors
8. Heating and Cooling Coils
9. Pumps
10. Boilers
11. Chillers
12. LP Gas supply system.

B. Training Modules: Develop a learning objective and teaching outline for each module. Include a description of specific skills and knowledge that participant is expected to master. For each module, include instruction for the following:

1. Basis of System Design, Operational Requirements and Criteria: Include system and equipment descriptions, operating standards, regulatory requirements, equipment function, operating characteristics, limiting conditions, and performance curves.
2. Documentation: Review emergency, operations, and maintenance manuals; Project Record Documents; identification systems; warranties and bonds; and maintenance service agreements.
3. Emergencies: Include instructions on stopping; shutdown instructions; operating instructions for conditions outside normal operating limits; instructions on meaning of warnings, trouble indications, and error messages; and required sequences for electric or electronic systems.
4. Operations: Include startup, control, and safety procedures; stopping and normal shutdown instructions; routine, normal, seasonal, and weekend operating instructions; operating procedures for emergencies and equipment failure; and required sequences for electric or electronic systems.
5. Adjustments: Include alignments and checking, noise, vibration, economy, and efficiency adjustments.
6. Troubleshooting: Include diagnostic instructions and test and inspection procedures.
7. Maintenance: Include inspection procedures, types of cleaning agents, methods of cleaning, procedures for preventive and routine maintenance, and instruction on use of special tools.
8. Repairs: Include diagnosis, repair, and disassembly instructions; instructions for identifying parts; and review of spare parts needed for operation and maintenance.

PART 3 - EXECUTION

3.1. GENERAL REQUIREMENTS

A. Facilitator: Engage a qualified facilitator to prepare instruction program and training modules, to coordinate instructors, and to coordinate between Contractor and Owner for number of participants, instruction times, and location.

B. Engage qualified instructors to instruct Owner's personnel to adjust, operate, and maintain systems, subsystems, and equipment not part of a system.

C. Scheduling: Provide instruction at mutually agreed on times. For equipment that requires seasonal operation, provide similar instruction at start of each season.

1. Schedule training with Owner with at least 30 days' advance notice.

D. Instruction Duration: Instructional time shall be no less than three (3) 8-hour days with an hour break for lunch, 8:00 am – 5:00 pm.

E. Document training attendance for each session.

END OF SECTION

SECTION 23 03 00 – HVAC UNDERGROUND UTILITIES WORK REQUIREMENTS

PART 1 - GENERAL

1.1. SUMMARY

A. This section includes excavation, backfill, piped utility demolition, tree protection, temporary erosion and sedimentation control, grout and flowable fill of Division 23 systems and equipment.

B. In projects with Division 31-33 specifications, this section is intended to supplement those requirements. Where there are conflicts, the strictest requirement shall apply.

1.2. SUBMITTALS

A. Delegated Design Submittals: Design of excavation support and protection methods and systems.

B. Construction Submittals:

1. Instruction Program: Submit outline of instructional program for demonstration and training including proposed dates, times, lengths of instruction times, instructor's name and instructor's qualifications.

C. Close-Out Submittals:

1. Record Drawings: Locating and identifying HVAC utilities within the project area, including sizes, dimensions, elevations, building and manhole entrances, crossing utilities, etc.

a. Photographic Documentation: Include photographs of original and final conditions including utilities while exposed in trenches. Key the photos to the record drawings to provide visual documentation of the underground conditions and locations of the utilities.

1.3. PRE-INSTALLATION MEETING

A. Pre-Installation Conference: Conduct conference at project site to review the following:

1. Existing utilities and subsurface conditions.

2. Coordination of utility interruptions.

3. Building and tree protection.

4. Proposed excavations and excavation support and protection strategy.

5. Proposed vehicle and pedestrian traffic plans.

6. Proposed flushing and testing plan.

1.4. FIELD CONDITIONS

A. Interruption of Existing Utilities: Do not interrupt any utility serving facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary utility according to requirements indicated:

1. Notify Owner/Engineer no fewer than 14 days in advance of proposed interruption of utility.

2. Do not proceed with interruption of utility without Owner's/Engineer's written permission.

B. Survey Work: Engage a qualified land surveyor or professional engineer to survey adjacent existing buildings, structures, and site improvements; establish exact elevations at fixed points to act as benchmarks. Clearly identify benchmarks and record existing elevations.

PART 2 - PRODUCTS

2.1. PERFORMANCE REQUIREMENTS

A. Provide, monitor and maintain excavation support and protection system capable of supporting excavation sidewalls and of resisting earth and hydrostatic pressures and superimposed and construction loads.

1. Contractor Design: Design excavation support and protection system, including comprehensive engineering analysis by a qualified professional engineer.

2. Prevent surface water from entering excavations by grading, dikes, or other means.

3. Install excavation support and protection systems without damaging existing buildings, structures, and site improvements adjacent to excavation.

4. Continuously monitor vibrations, settlements, and movements to ensure stability of excavations and constructed slopes and to ensure that damage to permanent structures is prevented.

2.2. MATERIALS

A. General: Provide materials that are either new or in serviceable condition.

B. Structural Steel: ASTM A 36/A 36M, ASTM A 690/A 690M, or ASTM A 992/A 992M.

C. Steel Sheet Piling: ASTM A 328/A 328M, ASTM A 572/A 572M, or ASTM A 690/A 690M; with continuous interlocks.

D. Corners: Site-fabricated mechanical interlock.

E. Wood Lagging: Lumber, mixed hardwood, nominal rough thickness of size and strength required for application.

F. Cast-in-Place Concrete: ACI 301, of compressive strength required for application.

G. Reinforcing Bars: ASTM A 615/A 615M, Grade 60, deformed.

H. Tiebacks: Steel bars, ASTM A 722/A 722M.

2.3. SOIL MATERIALS

A. Satisfactory Soils: ASTM D 2487 Soil Classification Groups GW, GP, GM, SW, SP, and SM, or a combination of these groups; free of rock or gravel larger than 3 inches in any dimension, debris, waste, frozen materials, vegetation, and other deleterious matter.

1. Obtain approved clean fill soil material off-site when satisfactory soil materials are not available on-site.

B. Unsatisfactory Soils: Soil Classification Groups GC, SC, CL, ML, OL, CH, MH, OH, and PT according to ASTM D 2487 or a combination of these groups.

1. Unsatisfactory soils also include satisfactory soils not maintained within 2 percent of optimum moisture content at time of compaction.

C. Sub-Base Material: Naturally or artificially graded mixture of natural or crushed gravel, crushed stone, and natural or crushed sand; ASTM D 2940; with at least 90 percent passing a 1-1/2-inch sieve and not more than 12 percent passing a No. 200 sieve.

D. Base Course: Naturally or artificially graded mixture of natural or crushed gravel, crushed stone, and natural or crushed sand; ASTM D 2940; with at least 95 percent passing a 1-1/2-inch sieve and not more than 8 percent passing a No. 200 sieve.

E. Bedding Course: Naturally or artificially graded mixture of natural or crushed gravel, crushed stone, and natural or crushed sand; ASTM D 2940; except with 100 percent passing a 1-inch sieve and not more than 8 percent passing a No. 200 sieve.

F. Drainage Course: Narrowly graded mixture of washed crushed stone or crushed or uncrushed gravel; ASTM D 448; coarse-aggregate grading Size 57; with 100 percent passing a 1-1/2-inch sieve and 0 to 5 percent passing a No. 8 sieve.

G. Sand: ASTM C 33; fine aggregate, natural, or manufactured sand.

2.4. GROUT

A. Description: ASTM C 1107, Grade B, non-shrink and non-metallic, dry hydraulic-cement grout with 5000 psi at 28 day compressive strength, suitable for indoor and outdoor applications.

2.5. FLOWABLE FILL

A. Description: ASTM C 150, Type I, low-strength portland-concrete, flowable-slurry mix with 100 to 200 psig at 28-day compressive strength.

2.6. WARNING TAPE

A. Warning Tape: Acid- and alkali-resistant polyethylene film warning tape manufactured for marking and identifying underground utilities, 6 inches wide and 4 mils thick, continuously inscribed with a description of the utility; colored as follows:

B. Detectable Warning Tape: Acid- and alkali-resistant polyethylene film warning tape manufactured for marking and identifying underground utilities, a minimum of 6 inches wide and 4 mils thick, continuously inscribed with a description of the utility, with metallic core encased in a protective jacket for corrosion protection, detectable by metal detector when tape is buried up to 30 inches deep; colored as follows:

1. Red: Electric.
2. Yellow: Gas, oil, steam, and dangerous materials.
3. Orange: Telephone and other communications.
4. Blue: Water systems.
5. Green: Sewer systems.

PART 3 - EXECUTION

3.1. PREPARATION

A. Protect structures, utilities, sidewalks, pavements, and other facilities from damage caused by settlement, lateral movement, undermining, washout, and other hazards that could develop during excavation support and protection system operations.

   1. Shore, support, and protect utilities encountered.

B. Install excavation support and protection systems to ensure minimum interference with roads, streets, walks, and other adjacent occupied and used facilities.

   1. Do not close or obstruct streets, walks, or other adjacent occupied or used facilities without permission from Owner and authorities having jurisdiction. Provide alternate routes around closed or obstructed traffic ways if required by authorities having jurisdiction.

C. Locate excavation support and protection systems clear of permanent construction so that construction and finishing of other work is not impeded.

D. Existing Utilities: Do not interrupt utilities serving facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary utility services according to requirements indicated:

   1. Notify Owner not less than 14 days in advance of proposed utility interruptions.
   2. Do not proceed with utility interruptions without Owner's written permission.

3.2. GENERAL EXCAVATION

A. Unclassified Excavation: Excavate to subgrade elevations regardless of the character of surface and subsurface conditions encountered. Unclassified excavated materials may include rock, soil materials, and obstructions. No changes in the Contract Sum or the Contract Time will be authorized for rock excavation or removal of obstructions.

   1. If excavated materials intended for fill and backfill include unsatisfactory soil materials and rock, replace with satisfactory soil materials.
   2. Remove rock to lines and grades indicated to permit installation of permanent construction without exceeding the following dimensions:

      a. 24-inches outside of concrete forms other than at footings.

b. 6-inches beneath bottom of concrete slabs on grade.

c. 6-inches beneath pipe in trenches, and the greater of 24-inches wider than pipe or 42-inches wide.

3. Blasting is prohibited.

3.3. EXCAVATION FOR UTILITY TRENCHES

A. Excavate trenches to indicated gradients, lines, depths, and elevations.

1. Beyond building perimeter, excavate trenches to allow installation of top of pipe below frost line.

B. Excavate trenches to uniform widths to provide the following clearance on each side of pipe or conduit. Excavate trench walls vertically from trench bottom to 12 inches higher than top of pipe or conduit, unless otherwise indicated.

1. Clearance: Minimum 12-inches each side of pipe or conduit.

C. Trench Bottoms: Excavate and shape trench bottoms to provide uniform bearing and support of pipes and conduit. Shape subgrade to provide continuous support for bells, joints, and barrels of pipes and for joints, fittings, and bodies of conduits. Remove projecting stones and sharp objects along trench subgrade.

1. For pipes and conduit less than 6 inches in nominal diameter and flat-bottomed, multiple-duct conduit units, hand-excavate trench bottoms and support pipe and conduit on an undisturbed subgrade.

2. For pipes and conduit 6-inches or larger in nominal diameter, shape bottom of trench to support bottom 90 degrees of pipe circumference. Fill depressions with tamped sand backfill.

3. Excavate trenches 6-inches deeper than elevation required in rock or other unyielding bearing material to allow for bedding course.

D. Trench Bottoms: Excavate trenches 4-inches deeper than bottom of pipe elevation to allow for bedding course. Hand excavate for bell of pipe.

1. Excavate trenches 6-inches deeper than elevation required in rock or other unyielding bearing material to allow for bedding course.

3.4. BACKFILL

A. Place backfill on subgrades free of mud, frost, snow, or ice.

B. Place and compact bedding course on trench bottoms and where indicated. Shape bedding course to provide continuous support for bells, joints, and barrels of pipes and for joints, fittings, and bodies of conduits.

C. Backfill trenches excavated under footings and within 18-inches of bottom of footings with satisfactory soil; fill with concrete to elevation of bottom of footings.

D. Provide 4-inch-thick, concrete-base slab support for piping or conduit less than 30 inches below surface of roadways. After installing and testing, completely encase piping or conduit in a minimum of 4-inches of concrete before backfilling or placing roadway sub-base.

E. Place and compact initial backfill of sub-base material, free of particles larger than 1-inch in any dimension, to a height of 12-inches over the utility pipe or conduit.

1. Carefully compact initial backfill under pipe haunches and compact evenly up on both sides and along the full length of utility piping or conduit to avoid damage or displacement of piping or conduit. Coordinate backfilling with utilities testing.

F. Backfill voids with satisfactory soil while installing and removing shoring and bracing.

G. Place and compact final backfill of satisfactory soil to final subgrade elevation.

H. Install warning tape directly above utilities, 12-inches below finished grade, except 6 inches below subgrade under pavements and slabs.

3.5. BACKFILL COMPACTION

A. Place backfill and fill soil materials in layers not more than 6-inches in loose depth for material compacted by heavy compaction equipment, and not more than 4-inches in loose depth for material compacted by hand-operated tampers.

B. For utility trenches, compact each layer of initial and final backfill soil material at 85-percent.

3.6. GROUTING

A. Mix and install grout for equipment base bearing surfaces, pump and other equipment base plates, and anchors.

B. Clean surfaces that will come into contact with grout.

C. Provide forms as required for placement of grout.

D. Avoid air entrapment during placement of grout.

E. Place grout, completely filling equipment bases.

F. Place grout on concrete bases and provide smooth bearing surface for equipment.

G. Place grout around anchors.

H. Cure placed grout.

3.7. SOLDIER PILES AND LAGGING

A. Install steel soldier piles before starting excavation. Extend soldier piles below excavation grade level to depths adequate to prevent lateral movement. Space soldier piles at regular intervals not to exceed allowable flexural strength of wood lagging. Accurately align exposed faces of flanges to vary not more than 2 inches from a horizontal line and not more than 1:120 out of vertical alignment.

B. Install wood lagging within flanges of soldier piles as excavation proceeds. Trim excavation as required to install lagging. Fill voids behind lagging with soil, and compact.

C. Install wales horizontally at locations indicated on Drawings and secure to soldier piles.

3.8. SHEET PILING

A. Before starting excavation, install one-piece sheet piling lengths and tightly interlock vertical edges to form a continuous barrier.

B. Accurately place the piling, using templates and guide frames unless otherwise recommended in writing by the sheet piling manufacturer. Limit vertical offset of adjacent sheet piling to 60 inches. Accurately align exposed faces of sheet piling to vary not more than 2 inches from a horizontal line and not more than 1:120 out of vertical alignment.

C. Cut tops of sheet piling to uniform elevation at top of excavation.

3.9. TIEBACKS

A. Drill, install, grout, and tension tiebacks. Test load-carrying capacity of each tieback and replace and retest deficient tiebacks.

1. Have test loading observed by a qualified professional engineer responsible for design of excavation support and protection system.

2. Maintain tiebacks in place until permanent construction is able to withstand lateral earth and hydrostatic pressures.

3.10. BRACING

A. Bracing: Locate bracing to clear columns, floor framing construction, and other permanent work. If necessary to move brace, install new bracing before removing original brace.

1. Do not place bracing where it will be cast into or included in permanent concrete work unless otherwise approved by Architect.

2. Install internal bracing if required to prevent spreading or distortion of braced frames.

3. Maintain bracing until structural elements are supported by other bracing or until permanent construction is able to withstand lateral earth and hydrostatic pressures.

3.11. FIELD QUALITY CONTROL

A. Survey-Work Benchmarks: Resurvey benchmarks regularly during installation of excavation support and protection systems, excavation progress, and for as long as excavation remains open. Maintain an accurate log of surveyed elevations and positions for comparison with original elevations and positions. Promptly notify Architect if changes in elevations or positions occur or if cracks, sags, or other damage is evident in adjacent construction.

B. Promptly correct detected bulges, breakage, or other evidence of movement to ensure that excavation support and protection system remains stable.

C. Promptly repair damages to adjacent facilities caused by installation or faulty performance of excavation support and protection systems.

3.12. TEMPORARY EROSION AND SEDIMENTATION CONTROL

A. Provide temporary erosion and sedimentation control measures to prevent soil erosion and discharge of soil-bearing water runoff or airborne dust to adjacent properties and walkways, according to a sediment and erosion control plan, specific to the site that complies with EPA 832/R-92-005 or requirements of authorities having jurisdiction, whichever is more stringent.

B. Inspect, repair, and maintain erosion and sedimentation control measures during construction until permanent vegetation has been established.

C. Remove erosion and sedimentation controls and restore and stabilize areas disturbed during removal.

3.13. TREE PROTECTION

A. Erect and maintain temporary fencing around tree protection zones before starting site clearing. Remove fence when construction is complete.

1. Do not store construction materials, debris, or excavated material within fenced area.

2. Do not permit vehicles, equipment, or foot traffic within fenced area.

3. Maintain fenced area free of weeds and trash.

B. Do not excavate within tree protection zones, unless otherwise indicated.

C. Where excavation for new construction is required within tree protection zones, hand clear and excavate to minimize damage to root systems. Use narrow-tine spading forks, comb soil to expose roots, and cleanly cut roots as close to excavation as possible.

1. Cover exposed roots with burlap and water regularly.

2. Temporarily support and protect roots from damage until they are permanently redirected and covered with soil.

3. Coat cut faces of roots more than 1-1/2 inches (38 mm) in diameter with an emulsified asphalt or other approved coating formulated for use on damaged plant tissues.

4. Backfill with soil as soon as possible.

D. Repair or replace trees and vegetation indicated to remain that are damaged by construction operations, in a manner approved by Architect.

1. Employ an arborist, licensed in jurisdiction where Project is located, to submit details of proposed repairs and to repair damage to trees and shrubs.

2. Replace trees that cannot be repaired and restored to full-growth status, as determined by Architect.

3.14. REMOVAL AND REPAIRS

A. Remove excavation support and protection systems when construction has progressed sufficiently to support excavation and earth and hydrostatic pressures. Remove in stages to avoid disturbing underlying soils and rock or damaging structures, pavements, facilities, and utilities.

1. Remove excavation support and protection systems to a minimum depth of 48 inches below overlying construction and abandon remainder.

2. Fill voids immediately with compacted backfill.

3. Repair or replace, as approved by Engineer, adjacent work damaged or displaced by removing excavation support and protection systems.

B. Disposal: Remove surplus soil material, unsuitable topsoil, obstructions, demolished materials, and waste materials including trash and debris, and legally dispose of them off Owner's property.

1. Separate recyclable materials produced during site clearing from other non-recyclable materials. Store or stockpile without intermixing with other materials and transport them to recycling facilities.

3.15. DISPOSAL OF SURPLUS AND WASTE MATERIALS

A. Disposal: Remove surplus satisfactory soil and waste material, including unsatisfactory soil, trash, and debris, and legally dispose of it off Owner's property.

END OF SECTION

SECTION 23 05 00 – HVAC FIRESTOPPING

PART 1 - GENERAL

1.1. SUMMARY

A. This section includes firestopping requirements and information for Division 23 and 25 work.

1.2. DEFINITIONS

A. Firestopping: The use of a material or combination of materials in a fire and/or smoke-rated structure (wall or floor) where it has been breached, so as to restore the integrity of the fire and/or smoke rating on that wall or floor.

B. System: The use of a specific firestop material or combination of materials in conjunction with a specific wall or floor construction type and a specific penetrant(s).

C. Barrier: Any bearing or non-bearing wall or floor that has an hourly fire and smoke rating.

D. Through-Penetration: Any penetration of a fire-rated wall or floor that completely breaches the barrier.

E. Membrane-Penetration: Any penetration in a fire and/or smoke-rated wall or floor/roof-ceiling assembly that breaches only one side of the barrier.

F. Approved Testing Agencies: Not limited to: Underwriters Laboratory (UL), Factory Mutual (FM), and Intertek Group (IG).

1.3. PERFORMANCE REQUIREMENTS

A. Penetrations: Provide through-penetration and membrane-penetration firestop systems that are produced and installed to resist the spread of fire, passage of smoke and other hot gases according to requirements indicated, to restore the original fire and smoke resistance rating of assembly penetrated.

B. Provide and install complete penetration firestopping systems that have been tested and approved by nationally accepted testing agencies per ASTM E814 or UL 1479 fire tests in a configuration that is representative of field conditions.

1. F-Rated Systems: Provide firestop systems with F-ratings indicated and as required by the Building Code.
2. T-Rated Systems: Provide firestop systems with T-ratings and F-ratings indicated and as required by the Building Code.
3. L- Rated Systems: Provide firestop systems with L- ratings less than 5cfm/sf.
4. W-Rated systems: Provide firestop systems that are resistant to water. For piping penetrations, provide moisture-resistant through-penetration firestop systems.

C. For penetrations involving non-metallic, CPVC, PVC, or plastic piping, tubing or conduit, provide firestop systems that are chemically compatible in accordance with Manufacturer requirements.

D. For penetrations involving insulated piping, provide firestop systems not requiring removal of insulation.

E. For penetrations involving fire or fire/smoke dampers, only firestop products approved by the damper manufacturer shall be installed in accordance with the damper installation instructions.

F. Firestopping products shall have flame spread ratings less than 25 and smoke-developed ratings less than 450, as determined per ASTM E 84, except firestop products installed in plenum spaces shall have a smoke developed rating less than 50.

G. Engineering Judgment (EJ): Where there is no specific third party tested and classified firestop system available for an installed condition, the Contractor shall obtain from the firestopping material manufacturer an Engineering Judgment (EJ) to be submitted to the Authority Having Jurisdiction (AHJ) and Engineer for approval. The EJ shall follow the State of Virginia Division of Engineering and Buildings (DEB) guidelines.

1.4. SUBMITTALS

A. Product Submittals:

1. Product Data: For each type of firestopping product selected. Manufacturers certification must verify that firestopping materials are free of asbestos, lead and contain volatile organic compounds (VOCs) within limits of the local jurisdiction. Include the following information:

    a. Design Listings: Submit system design listings, including illustrations, from a qualified testing and inspecting agency that is applicable to each firestop configuration.

    b. Installation Instructions: Submit the manufacturer’s installation instruction for each firestop assembly.

    c. Engineering Judgements: Where there is no specific third party tested and classified firestop system available for a particular configuration, the Contractor shall obtain from the firestopping material manufacturer an Engineering Judgment (EJ) for submittal.

    d. Firestop Schedule: Submit schedule itemizing the following:

        1) Manufacturer’s product reference numbers and/or drawing numbers.

        2) Listing agency’s design number.

        3) Penetrating Item Description/Limits: Material, size, insulated or uninsulated, and combustibility.

        4) Maximum allowable annular space or maximum size opening.

        5) Construction type.

        6) F rating and, if applicable, T, L, and W ratings.

1.5. QUALITY ASSURANCE

A. Provide firestopping system design listings from FM Global's "Building Materials Approval Guide", Intertek's "Directory of Listed Building Products", or UL's "Fire Resistance Directory" in accordance with the appropriate ASTM Standard(s).

B. Single Source Limitations: Obtain firestop systems for all conditions from a single manufacturer.

1. Materials from different firestop manufacturers shall not be installed in the same firestop system or opening.

C. Firestopping material shall be asbestos and lead free and shall not incorporate nor require the use of hazardous solvents.

D. Firestopping sealants must be flexible, allowing for normal movement.

E. Firestopping materials shall not shrink upon drying as evidenced by cracking or pulling back from contact surfaces such that a void is created.

F. Firestopping materials shall be moisture resistant and may not dissolve in water after curing.

G. Materials used shall be in accordance with the manufacturer's written installation instructions.

H. Installer Qualifications: Installing sub-contractor shall be approved by FM Global according to FM Global 4991, "Approval of Firestop Contractors," or complies with its "Qualified Firestop Contractor Program Requirements."

I. All firestop materials shall be installed prior to expiration date. Store and handle materials per manufacturer's instructions to prevent deterioration or damage due to moisture, temperature changes, contaminants, or other causes.

1.6. COORDINATION

A. Coordinate areas prior to firestopping installation with the Owner, Construction Manager and/or all other Contractors.

B. Coordinate construction of openings and penetrating items to ensure that firestopping assemblies are installed according to specified requirements. Opening shall not exceed maximum restrictions allowable for annular spacing per listing or acceptable Engineering Judgments.

C. Coordinate sizing of sleeves, openings, core-drilled holes, or cut openings to accommodate through-penetration firestop systems.

D. Do not conceal firestopping installations until the Owner's inspection agency or Authorities Having Jurisdiction have examined each installation.

E. Schedule firestopping after installation of penetrants and joints but prior to concealing or obstructing access to areas requiring firestopping.

PART 2 - PRODUCTS

2.1. MANUFACTURERS

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

1. Emerson / Nelson Firestop Products
2. Hilti
3. 3M, Fire Protection Products Division
4. Tremco

2.2. FIRESTOPPING

A. Firestopping products specified in system design listings by approved testing agencies may be used providing they conform to the construction type, penetrant type, annular space requirements and fire rating involved in each separate assembly.

B. Accessories: Provide components for each firestop system that is needed to install fill materials and to comply with "Performance Requirements" Article. Use only components specified by the firestopping manufacturer and by the approved testing agencies for the firestop systems indicated. Accessories include, but are not limited to the following items:

1. Permanent forming/damming/backing materials, including the following:
    a. Slag wool fiber insulation.
    b. Foams or sealants used to prevent leakage of fill materials in liquid state.
    c. Fire-rated form board.
    d. Polyethylene/polyurethane backer rod.
    e. Rigid polystyrene board.
2. Temporary forming materials.
3. Substrate primers.
4. Steel sleeves

C. All firestopping products and systems shall be designed and installed so that the basic sealing system will allow the full restoration of the thermal and fire resistance properties of the barrier being penetrated with minimal repair if penetrants are subsequently removed.

D. Mold Resistance: Provide penetration firestopping with mold and mildew resistance rating of zero (0) as determined by ASTM G21.

PART 3 - EXECUTION

3.1. GENERAL REQUIREMENTS

A. Provide firestop systems consisting of a material, or combination of materials installed to retain the integrity of fire resistance rated construction by maintaining an effective barrier against the spread of flame, smoke and/or hot gases through penetrations, fire resistive joints, and perimeter openings in accordance with the requirements of the Building Code for this project.

B. Firestop systems shall be used in locations including, but not limited to, the following:

1. Penetrations through fire resistance rated floor and roof assemblies including both empty openings and openings containing penetrants.

2. Penetrations through fire resistance rated wall assemblies including both empty openings and openings containing penetrants.

3. Membrane penetrations in fire resistance rated wall assemblies where items penetrate one side of the barrier.

3.2. EXAMINATION

A. Examine substrates and conditions for compliance with requirements for opening configurations, penetrating items, substrates, and other conditions affecting performance.

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

C. Verify that all pipes, conduits, cables, and/or other items which penetrate fire-rated construction have been permanently installed prior to installation of firestops.

3.3. PREPARATION

A. Surface Cleaning: Clean out openings immediately before installing firestop systems to comply with written recommendations of firestopping manufacturer and the following requirements:

B. Remove from surfaces of opening substrates and from penetrating items foreign materials that could interfere with adhesion of firestop systems.

C. Clean opening substrates and penetrating items to produce clean, sound surfaces capable of developing optimum bond with firestop systems. Remove loose particles remaining from cleaning operation.

D. For those products requiring mixing before application, comply with firestopping manufacturer's written instructions for accurate proportioning of materials, water (if required), type of mixing equipment, selection of mixer speeds, mixing containers, mixing time, and other items or procedures needed to produce products of uniform quality with optimum performance characteristics for application indicated.

3.4. INSTALLATION

A. General: Install firestop systems to comply with firestopping manufacturer's written installation instructions and published drawings for products and applications indicated.

B. Apply firestopping in accordance with approved testing agencies listed system designs or manufacturer's EJ per the manufacturer's installation instructions.

C. Verify that environmental conditions are safe and suitable for installation of firestop products. Application areas shall be protected from weather, dry and within recommended temperature and humidity ranges of materials being installed.

D. Install forming/damming/backing materials and other accessories required to support fill materials during their application and in the position needed to produce cross-sectional shapes and depths required to achieve fire resistance ratings required.

E. Install metal framing, mechanical attachments, safing materials and firestop materials as applicable within the system design.

F. Install fill materials for firestop systems by proven techniques to produce the following results:

1. Fill voids, joints and cavities formed by openings, forming materials, accessories, and penetrating items as required to achieve fire-resistance ratings indicated.

2. Apply materials so they fully contact and adhere to substrates formed by openings and penetrating items.

3. For fill materials that will remain exposed after completing work, finish to produce smooth, uniform surfaces that are flush with adjoining finishes.

4. Tool non-sag firestop materials after their application and prior to the time skinning begins. Use tooling agents approved by the firestopping manufacturer.

G. On vertical pipe penetrations, lift riser clamps to permit the installation of firestopping around the entire pipe penetration. For penetrations involving fire or fire/smoke dampers, only firestop products approved by the damper manufacturer shall be installed in accordance with the damper installation instructions.

H. Label penetration ratings and UL detail numbers on wall surfaces directly adjacent to the penetrations. This information shall be readily visible in non-occupied spaces, within chases and above ceilings.

1. Comply with Section 230553 for identification and labeling requirements.

3.5. FIELD QUALITY CONTROL

A. Inspecting Agency: Authorities Having Jurisdiction, the Owner, or Owner’s Representative shall be allowed to perform random destructive testing during inspection of firestop systems to verify compliance per listings or manufacturer’s installation instructions. All areas of work must be accessible until inspection by the applicable Authorities Having Jurisdiction and inspection agencies. The contractor shall be responsible to repair all tested assemblies with no cost to the owner.

1. Refer to Division 1 and Section 230100 regarding Special Inspections requirements.

B. Proceed with enclosing firestop systems with other construction only after inspections are complete.

C. Where deficiencies are found as determined by the Engineer, remove and replace firestop systems so they comply with requirements.

3.6. CLEANING AND PROTECTION

A. Clean off excess fill materials adjacent to openings, as work progresses by methods and with cleaning materials that are approved in writing by firestopping manufacturer(s) and that do not damage materials in which openings occur. Leave finished work in neat, clean condition with no evidence of spillovers or damage to adjacent surfaces.

B. Provide final protection and maintain conditions during and after installation that ensure firestop systems are without damage or deterioration at time of Owner Acceptance. If, despite such protection, damage or deterioration occurs, cut out and remove damaged or deteriorated firestop systems immediately and install new materials to produce firestop systems complying with specified requirements.

END OF SECTION

SECTION 23 05 11 – HVAC ELECTRICAL PROVISIONS

PART 1 - GENERAL

1.1. SUMMARY

A. This section includes electrical equipment, materials and work that are the responsibility of Division 23.

1.2. SUBMITTALS

A. Product Submittals:

1. Product Data: For each type of device, include dimensions, mounting arrangements, location for conduit entries, shipping and operating weights, and manufacturer's technical data on features, performance, electrical ratings, characteristics, and finishes.

2. Electrical Connections: Submitted equipment nameplates shall be coordinated with the indicated design electrical characteristics. If the submitted equipment requires changes to the electrical connection(s) (including conduit, wire, circuit breaker, fuse, starter, and disconnect sizes, connection locations, etc.) comply with the requirements of Section 230100. Any changes required to accommodate the equipment shall be responsibility of the contractor.

a. Proposed changes to the design shall be submitted to the Engineer for review and approval.

b. Accepted changes shall be noted by the contractor on the as-built documentation.

B. Close-Out Submittals:

1. Operation and Maintenance Data: For disconnects, motor starters and combination motor starters and disconnects, to include in emergency, operation and maintenance manuals.

1.3. QUALITY ASSURANCE

A. Source Limitations: Obtain motor starters, disconnect switches and combination motor starters and disconnect switches of a single type through one source from a single manufacturer.

1. Exceptions: Disconnect switches that are factory-mounted to HVAC equipment may be provided by the equipment manufacturer.

B. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

1. Where requirements of Division 23, Division 26 or NFPA 70 conflict, conform to the strictest requirements.

C. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

1.4. EXTRA MATERIALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fuses: One set for each fused device.

PART 2 - PRODUCTS

2.1. EQUIPMENT ENCLOSURES

A. Provide NEMA-rated equipment enclosures for all disconnect switches, motor starters, control panels, variable speed controllers and other similar electrical equipment. When not otherwise indicated, provide enclosures based on the environments of the installations.

1. Inside, Clean Spaces without Water Piping: NEMA 1.
2. Inside, Utility Spaces and Spaces with Water Piping: NEMA 12.
3. Outside, Normal Ambient Conditions: NEMA 3R.
4. Inside or Outside, Water Features and Equipment (Pools, Fountains, Aquariums, etc.) Spaces: NEMA 4X
5. Inside or Outside, Manholes, Tunnels and Sumps: NEMA 6
6. Inside or Outside, NEC Hazard Class 1 Locations: NEMA 8
7. Inside or Outside, NEC Hazard Class 2 Locations: NEMA 9

2.2. DISCONNECT SWITCHES

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

1. Eaton
2. ABB/General Electric
3. Schneider Electric/Square D
4. Siemens

B. Fusible Disconnect Switches: Single-throw, heavy-duty, service-rated fusible switch, rated for 200 to 600Vac and labeled and listed UL 98 and NEMA KS 1, Type HD with silver-tungsten type fuse clips and equipment ground and neutral kit. When a neutral is not necessary, bond the neutral bus to the enclosure for use as grounding bus. Internal current-carrying components shall be solid copper. Provide auxiliary contacts when needed for control system interface.

C. Non-Fusible Disconnect Switches: Single-throw, heavy-duty, service-rated switch, rated for 200 to 600Vac and labeled and listed UL 98 and NEMA KS 1, Type HD with equipment ground and neutral kit. When a neutral is not necessary, bond the neutral bus to the enclosure for use as grounding bus. Internal current-carrying components shall be solid copper. Provide auxiliary contacts when needed for control system interface.

D. Provide switch accessories required to meet the system requirements indicated.

2.3. MOTOR STARTERS

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

1. Eaton
2. ABB/General Electric
3. Schneider Electric/Square D
4. Siemens

B. Description: Full-voltage, electrically-held, non-reversing, magnetic motor controllers with 24Vac control circuit, hand-off-auto (HOA) switch, push-to-start switch, manual reset switch, auxiliary control and monitoring contacts and accessories required to meet the system requirements indicated. Cover door shall have red and green pilot lights. The green light shall illuminate when “on”, and red shall illuminated when “off”.

2.4. COMBINATION MOTOR STARTERS AND DISCONNECT SWITCHES

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

1. Eaton
2. ABB/General Electric
3. Schneider Electric/Square D
4. Siemens

B. Description: Combination magnetic motor starter and circuit breaker disconnecting means with auxiliary contacts.

1. Disconnecting Means: Thermal magnetic type molded-case circuit breaker (MCCB) with adjustable instantaneous-trip for each pole, auxiliary control and monitoring contacts and test trip button.
2. Motor Starter: Full-voltage, electrically-held, non-reversing, magnetic motor controllers with 24Vac control circuit, hand-off-auto (HOA) switch, push-to-start switch, manual reset switch, auxiliary control and monitoring contacts and accessories required to meet the system requirements indicated. Cover door shall have red and green pilot lights. The green light shall illuminated when “on”, and red shall illuminated when “off”.

2.5. MANUAL MOTOR SWITCHES

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

1. Eaton

2. ABB/General Electric

3. Schneider Electric/Square D

4. Siemens

B. Description: Manual motor starter and disconnect switch with thermal overload protection for fractional horsepower motors. Toggle switch shall provide manual “on/off” control of one or two-pole single-phase motors rated up to 1 horsepower. The enclosure shall have green pilot light. The green light shall illuminate when “on”. The switch shall have a hand guard to prevent accidental operation and provisions for a padlock in the “off” position. The switch shall be rated for single or two-speed applications as indicated. The enclosure shall be for flush wall-mounting where possible and surface wall-mounting where not.

2.6. FUSES

A. Description: Non-renewable cartridge fuses of the type and size required by NFPA 70 and Division 26.

2.7. SHORT-CIRCUIT CURRENT RATINGS

A. Overcurrent protection devices shall be rated for the ampere interruption current rating indicated in the Division 26 documents. Where the rating is not indicated, provide devices rated for 65,000 AIC.

2.8. POWER AND CONTROL CABLING AND RACEWAY

A. Low-Voltage (100 to 600 V) Power Feeders: Size conductors and raceway per NFPA 70 and Division 26 based on equipment nameplate requirements and manufacturer’s installation recommendations.

B. Control-Voltage (Up to 24 V) Cabling: Provide control cabling for HVAC system per NFPA 70 and Division 26 based on the system manufacturer’s installation recommendations.

1. Paired Cabling: No. 16 AWG Type CMP plenum-rated twisted pair.

2. Class 1 and 2 Control Circuits: Stranded copper Type THHN-THWN.

3. Class 3 Control Circuits: Stranded copper Type TW or TF.

C. Power Conductors: Copper, solid for No. 10 AWG and smaller and stranded for No. 8 AWG and larger, with THHN-THWN insulation. Aluminum conductors will not be accepted.

D. Grounding Conductors: Copper, solid for No. 8 AWG and smaller and stranded for No. 6 AWG and larger, with THHN-THWN insulation. Aluminum conductors will not be accepted.

E. Conduit:

1. EMT (electrical metallic tubing): Indoor, above-grade applications not subject to damage.

2. RGS (rigid galvanized steel): Indoor, above-grade applications subject to damage and outdoor, above-grade applications.

3. RNC (rigid non-metallic conduit), Type Schedule 40 PVC: Indoor and outdoor, below-grade applications.

4. FMC (flexible metallic conduit): Indoor, above-ceiling applications.

5. LFMC (liquid-tight flexible metal conduit): Outdoor, above-grade applications.

PART 3 - EXECUTION

3.1. INSTALLATION

A. Disconnect Switches: Provide disconnect switches for all HVAC equipment. Disconnect switches shall be sized to comply with NFPA 70. Single fan, blower and pump motors shall be based on nameplate horsepower. All other applications shall be based on nameplate total kW rating. Disconnects shall be provided with dual-element fuses sized based on equipment nameplate rating.

1. Service Disconnect Switches: Where the disconnecting means is not within the line-of-sight, as defined by NFPA 70 and the authority having jurisdiction (AHJ), an additional service disconnect shall be located adjacent to the equipment it feeds.

DISCONNECT SWITCH SIZES for MOTORS						
AMPERAGE RATING	MAX HP at VOLTAGE/PHASE					
	115V/1ph	200V/1ph	230V/1ph	200V/3ph	230V/3ph	460V/3ph
30A	1.5	3	3	5	7.5	15
60A	3	7.5	10	15	15	30
100A	-	-	-	25	25	60
200A	-	-	-	50	60	100
400A	-	-	-	100	125	250

DISCONNECT SWITCH SIZES for EQUIPMENT							
AMPERAGE RATING	MAX KW at VOLTAGE/PHASE						
	120V/1ph	208V/1ph	240V/1ph	277V/1ph	208V/3ph	240V/3ph	480V/3ph
30A	2.8	5.0	5.8	6.6	8.6	10.0	19.9
60A	5.8	10.0	11.5	13.3	17.3	19.9	39.9
100A	9.6	16.6	19.2	22.2	28.8	33.2	66.4
200A	19.2	33.3	38.4	44.3	57.6	66.4	132.9
400A	38.4	66.6	76.8	88.6	115.1	132.9	265.7
600A	57.6	99.8	115.2	133.0	172.7	199.3	398.6

B. Motor Starters: Provide all motor starters where required for HVAC equipment to operate as intended. Motor starters shall be sized to comply with NFPA 70 and NEMA rated for magnetic starters.

NEMA STARTER SIZES					
NEMA SIZE	MAX HP at MOTOR VOLTAGE/PHASE				
	115V/1ph	230V/1ph	200V/3ph	230V/3ph	460V/3ph

00	0.33	1	1.5	1.5	2
0	1	2	3	3	5
1	2	3	7.5	7.5	10
2	-	7.5	10	15	25
3	-	-	25	30	50
4	-	-	40	50	100
5	-	-	75	100	200

C. Combination Motor Starters and Disconnect Switches: Provide combination motor starters and disconnect switches that meet the requirements of the "Motor Starters" article above. Combination motor starters and disconnect switches shall be used unless otherwise noted or prohibited by NFPA 70.

D. Manual Motor Switches: Provide manual motor switches for fractional horsepower fan, blower and pump motors that do not require automated start and stop functions.

E. Furnish and install devise fuses per equipment unit nameplate.

F. Size and adjust circuit breaker disconnect switches per equipment unit nameplate.

G. Electrical Connections: All electrical connections shall be made in accordance with equipment manufacturer's recommendations and in accordance with NFPA 70. Install and ground equipment connections in accordance with the requirements of NFPA 70 and Division 26.

1. Electrical Connections, Low Voltage (100 to 600 V): Division 23 contractor is responsible for power wiring and conduit from the equipment connections to the disconnecting means. Division 26 is responsible for the power circuit from the power source to the disconnecting means.

2. Electrical Connections, Control Voltage (Up to 24 V): Division 23 contractor is responsible for all control voltage wiring and conduit for HVAC equipment and controls from the low voltage power source disconnecting means. Division 26 is responsible for the low voltage power circuit from the power source to the disconnecting means.

   a. Low Voltage Disconnecting Means: Where dedicated low voltage circuits are indicated in Division 26 documents, the disconnecting means shall be defined as the disconnect switch or junction box provided. Where dedicated low voltage circuits are not explicitly indicated in Division 26 documents, the disconnecting means shall be defined as 20A/1P spare circuit breakers in panelboards.

H. Wiring Pathway, Low and Control Voltage: All low and control voltage power and control wiring shall be installed in conduit unless otherwise noted.

1. Surface-mounted raceway may only be used when indicated or Engineer approved prior to installation. In most cases, conduits shall be installed within walls, above ceilings and below floor slabs. Cut and repair substrates to install raceway.

2. Control voltage cabling shall be plenum-rated and organized with J-hooks when control cabling is not required by the Engineer to be installed in conduit.

I. Conduit:

1. Flexible Connections: Provide flexible connections for all vibrating equipment including fans, pumps, compressors, etc. Flexible connections shall be no more than 24-inches long.

2. Areas Subject to Damage: In areas where the conduit will be exposed and is subject to damage, such as mechanical equipment rooms, RGS conduit shall be installed to no less than 8-feet above finished floor and EMT may be used above 8-feet.

J. Grounding and Bonding: Ground and bond equipment and circuits in accordance with the requirements of NFPA 70 and Division 26.

K. Install duct-mounted smoke detectors, furnished and wired by Division 26. Provide duct access doors for proper maintenance and access.

L. Smoke-rated life-safety dampers shall be wired and controlled by Division 26.

M. Smoke control system devices shall be wired and controlled by Division 26.

3.2. FIELD QUALITY CONTROL

A. Comply with NFPA 70E per OSHA 29CFR Part 1910.5, Appendix A.

3.3. DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain electrical devices.

END OF SECTION

SECTION 23 05 13 – HVAC EQUIPMENT MOTORS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes general requirements for all HVAC motors

1.2. QUALITY ASSURANCE

A. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

B. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

PART 2 - PRODUCTS

2.1. GENERAL MOTOR REQUIREMENTS

A. Comply with NEMA MG 1 unless otherwise indicated.

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

C. Motors for fans and pumps shall be selected for the maximum brake-horsepower listed in the equipment schedules and no more than 85% of the nominal rated horsepower excluding the service factor.

2.2. MOTOR CHARACTERISTICS

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

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

2.3. POLYPHASE MOTORS

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

   1. General Use: Open drip-proof (ODP) motors.

B. Efficiency: All motors shall be Premium Efficiency conforming to the requirements of NEMA MG1 Part 31. Conform to 10 CFR Part 431 published by the US Department of Energy - Efficiency standard for integral horsepower motors.

1. Minimum efficiency shall meet the requirements of the State Energy Conservation Code and ASHRAE 90.1.

C. Service Factor: 1.15.

1. Multispeed Motors: Variable torque.

2. For motors with 2:1 speed ratio, consequent pole, single winding.

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

D. Rotor: Random-wound, squirrel cage.

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

F. Temperature Rise: Class B.

G. Insulation: Class F.

H. 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.

I. 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. Inverter-Duty Motors: Motors shall be “Inverter-Duty” rated according to NEMA MG 1 Part 31, “Requirements for Definite Purpose Inverter-Fed Polyphase Motors”, with minimum Class F temperature rise and Class H insulation. NEMA duty rating code on motor nameplate shall indicate “Inverter-Duty”. Other duty rating code markings such as “Inverter-Ready” are not acceptable.

3. Shaft Grounding Rings (SGR): Motors 5 hp and larger shall have solid or split type shaft grounding rings designed to prevent bearing damage due to adjustable speed drive induced currents. SGR shaft diameter shall match the motor’s standard NEMA “u” dimension.

4. Shaft Grounding Rings (SGR): Multi-phase motors shall have solid or split type shaft grounding rings designed to prevent bearing damage due to adjustable speed drive

induced currents. SGR shaft diameter shall match the motor's standard NEMA "u" dimension.

5. Over-Speeding: Variable frequency drives shall not be set above 60 Hz.

    a. Exceptions:

        1) Air Handling Units: Variable frequency drives shall not operate over 75 Hz and motors shall not operate over 3,000 RPM for direct-drive fans.

6. Under-Speed Operation: Motors shall be capable of continuous operation at minimum design operating speed indicated on the drawings. Where minimums are not indicated, motors shall be capable of continuous operation at the following minimum speeds.

    a. Fans: 18 Hz (30-percent).

    b. Pumps: 12 Hz (20-percent).

C. Electronically-Communicated (EC) Motors

1. Electronically-communicated (EC) motors, also known as brushless DC electric (BLDC) motors, shall be NEMA MG 1, totally enclosed fan cooled (TEFC), inverter-use, motors with integrated microprocessor speed controller designed for variable speed and torque fan and pump applications.

    a. Speed controller shall be programmed with safeties to avoid damaging conditions and unstable fan / pump operation. Firefighter's safety override mode shall allow bypass of most speed controller safeties.

    b. Speed controller shall comply with requirements of Section 230514.

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.

2. Split phase.

3. Capacitor start, inductor run.

4. Capacitor start, capacitor run.

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

C. Bearings: Pre-lubricated, 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

SECTION 23 05 14 – VARIABLE SPEED CONTROLLERS

PART 1 - GENERAL

1.1. SUMMARY

A. This section includes solid-state, pulse-width modulated, variable speed motor controllers for three-phase, squirrel-cage induction motors.

1.2. SUBMITTALS

A. Product Submittals:

1. Product Data: For each type of variable speed controller, include dimensions, mounting arrangements, location for conduit entries, shipping and operating weights, and manufacturer's technical data on features, performance, electrical ratings, characteristics, and finishes.

2. Seismic Qualification Certificates: Provide certification for the equipment and its components and accessories that they have been tested and meet the requirements for use in seismic applications in accordance with Virginia Construction Code.

B. Close-Out Submittals:

1. Operation and Maintenance Data: For variable speed controllers, all installed devices, and components to include in emergency, operation, and maintenance manuals.

a. Routine maintenance requirements for variable speed controllers and all installed components.

b. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.

2. Load-Current and Overload-Relay Heater List: Compile after motors have been installed and arrange to demonstrate that selection of heaters suits actual motor nameplate full-load currents.

3. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that dip switch settings for motor running overload protection suit actual motor to be protected.

1.3. QUALITY ASSURANCE

A. Manufacturer Qualifications: A qualified manufacturer. Maintain, within 100 miles of Project site, a service center capable of providing training, parts, and emergency maintenance and repairs.

B. Source Limitations: Obtain variable speed controllers of a single type through one source from a single manufacturer.

1. Exceptions: Variable speed controllers that are factory-mounted to HVAC equipment, such as chillers and cooling towers, and branded by the equipment manufacturer may be provided by the equipment manufacturer.

C. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

D. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

E. Product Selection for Restricted Space: Drawings indicate maximum dimensions for variable speed controllers minimum clearances between the controllers and adjacent surfaces and other items. Comply with indicated maximum dimensions and clearances.

1.4. PERFORMANCE REQUIREMENTS

1.5. DELIVERY, STORAGE, AND HANDLING

A. Deliver variable speed controllers in shipping splits of lengths that can be moved past obstructions in delivery path as indicated.

B. Store variable speed controllers indoors in clean, dry space with uniform temperature to prevent condensation. Protect controllers from exposure to dirt, fumes, water, corrosive substances, and physical damage.

1.6. PROJECT CONDITIONS

A. Environmental Limitations: Rate equipment for continuous operation, capable of driving full load without de-rating, under the following conditions, unless otherwise indicated:

1. Ambient Temperature: 32 to 105 deg F.

2. Humidity: Less than 90 percent (non-condensing).

3. Altitude: Not exceeding 3300 feet.

B. NEMA-rated enclosures for the installed environment. Refer to Section 230511.

1.7. COORDINATION

A. Coordinate layout and installation of variable speed controllers with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Coordinate installation of roof curbs, equipment supports, and roof penetrations.

C. Coordinate features of variable speed controllers, installed units, and accessory devices with pilot devices and control circuits to which they connect.

D. Coordinate features, accessories, and functions of each variable speed controller and each installed unit with ratings and characteristics of supply circuit, motor, required control sequence, and duty cycle of motor and load.

1.8. WARRANTY

A. Special Warranty: Manufacturer's complete parts and labor warranty for 3-years from the date of Owner Acceptance.

1.9. EXTRA MATERIALS

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. Spare Fuses: One set of three for each variable speed controller.
2. Indicating Lights: Two of each type installed.

PART 2 - PRODUCTS

2.1. MANUFACTURERS

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

1. ABB.
2. Danfoss.
3. Eaton/Cutler-Hammer.
4. Emerson Industrial Automation
5. JCI (ABB Rebranded)
6. Schneider Electric/Square D.
7. Yaskawa.

2.2. VARIABLE FREQUENCY CONTROLLERS

A. Description: NEMA 2, integrated-gate bipolar transistor (IGBT), pulse-width modulated (PWM), variable frequency controller listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, 3-phase induction motor by adjusting output voltage and frequency. Provide unit suitable for operation of premium efficiency motor as defined by NEMA MG 1.

1. Provide 6, 12 or 18-pulse drives as needed to meet the harmonic distortion limits.
2. Provide 12-pulse minimum drives on equipment with a total motor horsepower of 100 hp or more.

B. 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.

C. Output Rating: 3-phase; 6 to 66 Hz, with torque constant as speed changes.

D. Unit Operating Requirements:

1. Input ac voltage tolerance of 208 V, plus or minus 5 percent; 380 to 500 V, plus or minus 10 percent; and 525 to 575 V, plus or minus 10 percent.
2. Input frequency tolerance of 50/60 Hz, plus or minus 6 percent.
3. Minimum Efficiency: 96 percent at 60 Hz, full load.
4. Minimum Displacement Primary-Side Power Factor: 96 percent.
5. Overload Capability: 1.1 times the base load current for 60 seconds; 2.0 times the base load current for 3 seconds.
6. Starting Torque: 100 percent of rated torque or as indicated.
7. Speed Regulation: Plus or minus 1 percent.

E. Isolated control interface to allow controller to follow control signal over an 11:1 speed range with an electrical signal of 4 to 20 mA at 24V.

F. 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: 2 to a minimum of 22 seconds.
4. Deceleration: 2 to a minimum of 22 seconds.
5. Current Limit: 50 to a minimum of 110 percent of maximum rating.
6. Self-Protection and Reliability Features:
7. Input transient protection by means of surge suppressors.
8. Under and over-voltage trips; inverter over-temperature, overload, and overcurrent trips.
9. Motor Overload Relay: Adjustable and capable of NEMA 2, Class 20 performance.
10. Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
11. Instantaneous line-to-line and line-to-ground overcurrent trips.
12. Loss-of-phase protection.
13. Reverse-phase protection.
14. Short-circuit protection.
15. Motor over-temperature fault.

G. Multiple-Motor Capability: Controller suitable for service to multiple motors and having a separate overload relay and protection for each controlled motor. Overload relay shall shut off controller and motors served by it when overload relay is tripped.

H. Automatic Reset/Restart: Attempts three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Bidirectional auto-speed search shall be capable of starting into rotating loads spinning in either direction and returning motor to set speed in proper direction, without damage to controller, motor, or load.

I. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped.

J. 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.

K. 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.

L. Input Line Conditioning: 5% Line Reactor.

M. VFC Output Filtering: Load reactors (dV/dt filters) for distances greater than 50 feet between drive and load.

N. Status Lights: Door-mounted LED indicators shall indicate the following conditions:

1. Power on.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
6. External fault.

O. Panel-Mounted Operator Station: Start-stop and auto-manual selector switches with manual speed control potentiometer and elapsed time meter.

P. Indicating Devices: Meters or digital readout devices and selector switch, mounted flush in controller door and connected to indicate the following controller parameters:

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 (Vdc).

9. Set-point frequency (Hz).

10. Motor output voltage (V).

Q. Control Signal Interface:

1. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.

2. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the building automation system (BAS) or other control systems:

   a. 0 to 10-V dc.

   b. 0-20 or 4-20 mA.

   c. Potentiometer using up/down digital inputs.

   d. Fixed frequencies using digital inputs.

   e. RS485.

   f. Keypad display for local hand operation.

3. Output Signal Interface: Minimum of 1 analog output signal (0/4-20 mA), which can be programmed to any of the following:

   a. Output frequency (Hz).

   b. Output current (load).

   c. DC-link voltage (VDC).

   d. Motor torque (percent).

   e. Motor speed (rpm).

   f. Set-point frequency (Hz).

4. Remote Indication Interface: A minimum of 2 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 (over-temperature or overcurrent).

   d. PID high- or low-speed limits reached.

R. Communications: Provide an RS485 interface allowing variable frequency controller to be used with an external system within a multi-drop local area network (LAN) configuration. Interface shall allow all parameter settings of variable frequency controllers to be programmed via building automation system (BAS) control. Provide capability for variable frequency controllers to retain these settings within the nonvolatile memory.

1. BAS Interface: Factory-installed hardware and software to enable the building automation system (BAS) to monitor, control and display unit status and alarms. BACnet

communication interface with the BAS shall enable the BAS operator to remotely control and monitor the unit from an operator workstation. Control features and monitoring points displayed locally at unit control panel shall be available through the BAS.

S. Manual Bypass: Magnetic contactor arranged to safely transfer motor between controller output and bypass controller circuit when motor is at zero speed. Controller-off-bypass selector switch sets mode, and indicator lights give indication of mode selected. Unit shall be capable of stable operation (starting, stopping, and running), with motor completely disconnected from controller (no load).

T. Bypass Controller: NEMA 2, full-voltage, non-reversing enclosed controller with across-the-line starting capability in manual-bypass mode. Provide motor overload protection under both modes of operation with control logic that allows common start-stop capability in either mode.

U. Integral Disconnecting Means: Door interlocked, NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than 65,000A.

V. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.

2.3. ENCLOSURES

A. Provide NEMA-rated enclosure appropriate for the installed environment. Refer to Section 230511 for more information.

2.4. ACCESSORIES

A. Devices shall be factory installed in controller enclosure, unless otherwise indicated.

B. Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.

C. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.

D. Control Relays: Auxiliary and adjustable time-delay relays.

E. Standard Displays: Door mounted display shall include:

1. Output frequency (Hz).
2. Set-point frequency (Hz).
3. Motor current (amperes).
4. DC-link voltage (VDC).
5. Motor torque (percent).
6. Motor speed (rpm).
7. Motor output voltage (V).

F. 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.

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine areas, surfaces, and substrates to receive variable speed controllers for compliance with requirements, installation tolerances and other conditions affecting performance.

B. Examine roughing-in for conduit systems to verify actual locations of conduit connections before variable speed controllers installation.

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

3.2. APPLICATIONS

A. Select features of each variable speed controller to coordinate with ratings and characteristics of supply circuit and motor; required control sequence; and duty cycle of motor, controller, and load.

B. Select horsepower rating of controllers to suit motor controlled.

C. Select amperage rating of controllers to suit multiple motor applications.

D. Variable speed drives shall be furnished for each motor. Do not operate more than one motor on a single variable speed drive unless otherwise noted.

3.3. INSTALLATION

A. Anchor each variable speed controller assembly to steel-channel sills arranged and sized according to manufacturer's written instructions. Attach by bolting. Level and grout sills flush with mounting surface.

B. Comply with mounting and anchoring requirements specified in Division 26.

C. Controller Fuses: Install fuses in each fusible switch. Comply with requirements in Division 26.

D. Seal interior electronics in plastic wrap to protect from dirt during installation. Remove plastic wrap when complete. Cover enclosure vents with MERV-5 filter media prior to using VFD’s during construction. Keep VFD’s clean. Vacuum dirt and metal shavings from inside and outside of VFD enclosure.

3.4. IDENTIFICATION

A. Identify variable speed controllers, components, and control wiring according to Section 230553.

3.5. CONTROL WIRING INSTALLATION

A. Install wiring between variable speed controllers and remote devices according to Division 26.

B. Bundle, train, and support wiring in enclosures.

C. Connect hand-off-automatic switch and other automatic-control devices where applicable.

1. Connect selector switches to bypass only manual- and automatic-control devices that have no safety functions when switch is in hand position.

2. Connect selector switches with control circuit in both hand and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

3.6. CONNECTIONS

A. Conduit installation requirements are specified in Division 26. Drawings indicate general arrangement of conduit, fittings, and specialties.

B. Ground equipment according to Division 26.

C. VFD Cable:

1. Provide Type TC-ER: Comply with NEMA WC 70/ICEA S-95-658 and UL 1277. Cable designed for use with VFCs, with oversized crosslinked polyethylene insulation, spiral-wrapped foil plus 85 percent coverage braided shields and insulated full-size ground wire, and sunlight- and oil-resistant outer PVC jacket. Extra-flexible stranded for all sizes. Armoring is required for cable not installed in conduit.

3.7. FIELD QUALITY CONTROL

A. Factory-trained technician shall perform start-up.

1. Technician shall utilize manufacturer’s software with laptop to upload parameters in compliance with manufacturer’s warranty.

2. Start-ups shall be witnessed by the Owner and performed prior to TAB.

B. Perform the following field tests and inspections and prepare test reports:

1. Perform each electrical test and visual and mechanical inspection, except optional tests, stated in NETA ATS. Certify compliance with test parameters.

2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

3.8. ADJUSTING

A. Set field-adjustable switches and circuit-breaker trip ranges.

3.9. DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain variable frequency controllers.

END OF SECTION

SECTION 23 05 16 – EXPANSION FITTINGS AND LOOPS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes expansion joints, expansion loops, fittings, supports, guides and anchors.

1.2. ACTION SUBMITTALS

A. Product Submittals:

1. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1. PERFORMANCE REQUIREMENTS

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

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

2.2. FLEXIBLE HOSE TYPE EXPANSION COMPENSATORS

A. Flexible-Hose Expansion Loop: Manufactured assembly with inlet and outlet elbow fittings and two flexible-metal-hose legs joined by long-radius, 180-degree return bend or center section of flexible hose. Flexible hoses constructed of corrugated metal inner hoses and braided outer sheaths.

1. Copper Piping Systems: Copper alloy fittings with solder joint end connections for 2 inches NPS and smaller and threaded for 2-1/2 inches NPS and larger. Stainless steel hoses and single-braid stainless steel sheaths with 300 psig at 70 deg F and 225 psig at 450 deg F ratings.

2. Steel Piping Systems: Carbon steel fittings with threaded end connections for 2 inches NPS and smaller and flanged for 2-1/2 inches NPS and larger. Stainless steel hoses and single-braid stainless steel sheaths for 2 inches NPS and smaller and double-braid for 2-1/2 inches NPS and larger with 275 psig at 70 deg F and 200 psig at 600 deg F ratings.

2.3. ALIGNMENT GUIDES, SUPPORTS AND ANCHORS

A. Pipe Supports: Factory-fabricated steel sliding supports with 1/2-inch thick low-friction graphite on both upper and lower backing. Graphite plates shall be epoxy bonded and riveted to steel components. All pipe saddles shall be 3/8” minimum thickness. Advanced Thermal Systems or Engineer approved equal.

B. Alignment Guides: Factory-fabricated steel alignment guides with 1/2-inch thick low-friction graphite on both upper and lower backing plates and two-section guiding slider. Graphite plates shall be epoxy bonded and riveted to steel components. All pipe saddles shall be 3/8” minimum thickness. Advanced Thermal Systems or Engineer approved equal.

C. Anchors: Steel, factory-fabricated anchor. Zinc-coated mechanical fasteners shall be insert-wedge-type stud with expansion plug anchor for use in hardened Portland cement concrete, with tension and shear capacities appropriate for application.

D. All pipe supports, guides, anchors, and associated structural steel shall be provided with:

1. Shop-applied oxide primer meeting the following requirements:

a. One coat primer at 2.5-3.5 mils DFT (dry finish thickness)

b. Meet ASTM 4541 for adhesion with not less than 1150 psi

c. Meet ASTM 4585 for humidity with no more than 1% rust after 5,000 hours exposure.

d. Meet ASTM-D 2794 for impact with no visible cracking or delamination after 160 inch-pounds direct impact.

e. Meet ASTM B117 for salt spray with no more than 3% rust or plane, no more than 1/64 of an inch creep at scribe after 10,250 hours.

f. Clean per SSPC-SP3 power tool cleaning and meet slip co-efficient of 0.056.

2. Two-part polyamidoamine epoxy top coat meeting the following requirements:

a. Color: Red

b. 2 coats, 4-6 mils per coat for a total of 8-12 mils required for the top coat.

c. Meet ASTM 4541 Type II for adhesion with not less than 1600 psi pull, average of 3 tests.

d. Meet ASTM 4585 for humidity with no blistering, cracking, checking, rusting or delamination of film after 10,000 hours exposure.

e. Meet ASTM B117 for salt spray with no more than 1% rust or plane, no more than 1/64 of an inch creep at scribe after 10,000 hours.

f. Meet ASTM D 4060 for abrasion with no more than 180 mg loss after 1,000 cycles.

g. Meet ASTM D 1014 for exposure with no blistering, cracking, checking, rusting, or delamination of film after 5-years of exposure.

h. Meet ASTM D 870 for immersion with no blistering, cracking, checking, rusting or delamination of film after 2-years of continuous water immersion.

i. Meet ASTM D 1653 for vapor transmission with no more than 9.9 g/m2 in 24 hours (transmission) and no more than 0.31 g/SF per hour in hg (permeability).

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 expansion joints in the “cold” position, such that when piping is in service, expansion joints can accept the maximum allowable expansion.

C. Do not weld/ground across expansion joints per manufacturer’s recommendation.

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.

3.3. ALIGNMENT-GUIDE AND ANCHOR INSTALLATION

A. Install alignment guides to guide expansion and to avoid end-loading and torsional stress.

B. Install two guides on each side of pipe expansion fittings and loops.

C. Install guides nearest to expansion joint not more than four pipe diameters from expansion joint.

D. Install guides nearest to expansion joint where indicated on drawings and recommended by the manufacturer.

E. Attach guides to pipe, and secure guides to building structure.

F. Install anchors at locations to prevent stresses from exceeding those permitted by ASME B31.9 and to prevent transfer of loading and stresses to connected equipment.

G. Anchor Attachments:

1. Anchor Attachment to Steel Pipe: Attach by welding. Comply with ASME B31.9 and ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
2. Anchor Attachment to Copper Tubing: Attach with pipe hangers. Use MSS SP-69, Type 24; U bolts bolted to anchor.

H. Fabricate and install steel anchors by welding steel shapes, plates, and bars. Comply with ASME B31.9 and AWS D1.1/D1.1M.

1. Anchor Attachment to Steel Structural Members: Attach by welding.

2. Anchor Attachment to Concrete Structural Members: Attach by fasteners. Follow fastener manufacturer's written instructions.

I. Use grout to form flat bearing surfaces for guides and anchors attached to concrete.

END OF SECTION

SECTION 23 05 17 – SLEEVES AND SLEEVE SEALS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes sleeves, sleeve seals and associated materials.

1.2. SUBMITTALS

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

PART 2 - PRODUCTS

2.1. SLEEVES

A. Cast-Iron Wall Pipes: Cast or fabricated of cast or ductile iron and equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop unless otherwise indicated.

B. Galvanized-Steel Wall Pipes: ASTM A 53/A 53M, Schedule 40, with plain ends and welded steel collar; zinc coated.

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

D. Galvanized-Steel-Sheet Sleeves: Minimum 20-gauge thickness; round tube closed with welded longitudinal joint.

E. PVC pipe sleeves are not acceptable.

2.2. SLEEVE-SEAL SYSTEMS

A. Description: Modular sealing-element unit, designed for field-assembly for filling annular space between piping and sleeve. The sealing elements shall be interlocking links shaped to fit pipe surface. GPT Link-Seal or Engineer approved equal.

1. Piping Systems, 180 deg F and below:

a. Sealing Elements: EPDM-rubber or NBR (nitrile butadiene rubber).

b. Pressure Plates: Reinforced Nylon Polymer.

c. Connecting Bolts and Nuts: Stainless steel or carbon steel with corrosion resistance coating.

d. Constant Temperature Rating: 200 deg F.

2. Piping Systems, above 180 deg F:

a. Sealing Elements: Silicone.

b. Pressure Plates: Steel with corrosion resistance coating.

c. Connecting Bolts and Nuts: Stainless steel or carbon steel with corrosion resistance coating.

d. Constant Temperature Rating: 300 deg F.

B. PVC sleeve seal systems are not acceptable.

2.3. GROUT

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

B. Characteristics: Non-shrink; recommended for interior and exterior applications.

C. Design Mix: 5000-psi, 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.

1. Insulated piping systems shall have insulation continue through penetrations without interruption. Insulation joints shall not occur within sleeves.

B. For sleeves that will have sleeve-seal system installed, select sleeves of size large enough to provide 1-inch minimum 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 masonry walls as new slabs and walls are constructed.

1. Walls: Cut sleeves to length for mounting flush with both surfaces.

2. Floors: Extend sleeves 1-inch above finished floor and seal penetrations watertight.

3. Mechanical Equipment Room and Wet Area Floors: Extend sleeves 2-inches above finished floor and seal penetrations watertight.

4. 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. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.

3. Seal annular space between sleeve and piping or piping insulation; use joint sealants appropriate for size, depth, and location of joint. Comply with requirements of 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 and associated U.L. detail.

3.2. SLEEVE-SEAL-SYSTEM INSTALLATION

A. Install sleeve-seal systems in sleeves in exterior masonry walls and slabs-on-grade at service piping entries into building.

B. Select type, size, and number of sealing elements required for piping material and size and for sleeve ID or hole size. Position piping in center of sleeve. Center piping in penetration, assemble sleeve-seal system components, and install in annular space between piping and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make a watertight seal.

3.3. SLEEVE AND SLEEVE-SEAL SYSTEM SCHEDULE

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

1. Cast-Iron Pipe Sleeves with Sleeve Seal Systems: Masonry walls above and below grade and concrete slabs on grade.

   a. Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.

2. Galvanized Steel Pipe Sleeves: Interior fire-rated partitions; interior non-rated partitions; and concrete slabs above grade.

3. Galvanized Steel Sheet Sleeves: Interior non-rated partitions.

END OF SECTION

SECTION 23 05 19 – PIPING INSTRUMENTS AND GAGES

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes instruments and gages for HVAC systems.

1.2. SUBMITTALS

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

1. Product Certificates: For each type of instrument and gage from manufacturer.

B. Close-Out Submittals:

1. Operation and Maintenance Data: For instruments and gages to include in operation and maintenance manuals.

1.3. QUALITY ASSURANCE

A. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

B. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

PART 2 - PRODUCTS

2.1. THERMOMETERS

A. Standard: ASME B40.200.

B. Liquid-in-Glass Thermometers: 9-inch cast aluminum case with adjustable angle; glass tube with magnifying lens and blue or red organic liquid; non-reflective aluminum with permanently etched scale markings graduated in deg F and deg C; glass window; aluminum stem of length suitable for application for Thermowell installation; 1-1/4 inch connector with ASME B1.1 screw threads; and accuracy to plus or minus 1 percent of scale range.

C. Thermometer Scale Ranges for Piping Systems:

1. Chilled Water: 0 to 100 deg F.

2. Heating Water: 0 to 250 deg F.

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

2.2. THERMOWELLS

A. Standard: ASME B40.200.

B. Thermowells: Pressure-tight, socket-type fitting made for insertion into piping tee fitting.

1. Material for Use with Copper Tubing: Copper-nickel (90-10) or copper-nickel (70-30).

2. Material for Use with Steel Piping: Corrosion resistant steel.

3. Type: Stepped shank unless straight or tapered shank is indicated.

4. External Threads: NPS 1/2, NPS 3/4, or NPS 1, ASME B1.20.1 pipe threads.

5. Internal Threads: 1/2, 3/4, and 1 inch, with ASME B1.1 screw threads.

6. Bore: Diameter required to match thermometer bulb or stem.

7. Insertion Length: Length required to match thermometer bulb or stem.

8. Lagging Extension: Include on thermowells for insulated piping and tubing.

9. Bushings: For converting size of thermowell's internal screw thread to size of thermometer connection.

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

2.3. PRESSURE GAGES

A. Standard: ASME B40.100.

B. Dial-Type Pressure Gages: Oil-filled, cast aluminum case with 4-1/2 inch nominal diameter; non-reflective aluminum dial with permanently etched scale markings graduated in psi and kPa; bourbon tube pressure element assembly; brass pressure connection with NPS 1/4 or 1/2 inch ASME B1.20 pipe threads and bottom-outlet; mechanical movement with link pressure element and connection to pointer; glass window; stainless steel ring; dark colored metal pointer; and accuracy to plus or minus 1 percent of scale range.

C. Scale Ranges for Piping Systems:

1. Chilled Water: 0 to 100 psi.

2. Heating Water: 0 to 100 psi.

2.4. GAGE ATTACHMENTS

A. Snubbers: ASME B40.100, brass; with NPS 1/4 or NPS 1/2, ASME B1.20.1 pipe threads and surge-dampening device. Include extension for use on insulated piping.

B. Valves: Brass or stainless-steel needle, with NPS 1/4 or NPS 1/2, ASME B1.20.1 pipe threads.

2.5. TEST PLUGS

A. Test Plug: Test-station fitting made for insertion into piping tee fitting; brass or stainless steel body including extended stem when used on insulated piping; core inserts and gasketed and threaded cap; ASME B1.20.1 pipe threads; chlorosulfonated polyethylene synthetic and EPDM self-sealing rubber core inserts; rated for a minimum of 500 psig at 200 deg F.

2.6. TEST-PLUG KITS

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

B. Low-Range Thermometer: Small, bimetallic insertion type with 2-inch diameter dial and tapered-end sensing element. Dial range shall be at least 25 to 125 deg F.

C. High-Range Thermometer: Small, bimetallic insertion type with 2-inch diameter dial and tapered-end sensing element. Dial range shall be at least 0 to 220 deg F.

D. Pressure Gage: Small, Bourdon-tube insertion type with 2-inch diameter dial and probe. Dial range shall be at least 0 to 200 psig.

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

2.7. SIGHT FLOW INDICATORS

A. Sight Flow Indicators: Inline-installation device for visual verification of flow with sight glass and paddle wheel indicator; bronze or stainless-steel body; threaded end connections for NPS 2-inches and smaller and flanged end connections for NPS 2-1/2 inches and larger; and rated for minimum of 150 psig and 200 deg F.

PART 3 - EXECUTION

3.1. INSTALLATION

A. Install thermowells with socket extending to center of pipe and in vertical position in piping tees.

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

C. Install thermowells with extension on insulated piping.

D. Fill thermowells with heat-transfer medium.

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

F. Install remote-mounted thermometer bulbs in thermowells and install cases on panels; connect cases with tubing and support tubing to prevent kinks. Use minimum tubing length.

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

H. Install direct-mounted pressure gages in piping tees with pressure gage located on pipe at the most readable position.

I. Install remote-mounted pressure gages on panel.

J. Install valve and snubber in piping for each pressure gage for fluids (except steam).

K. Install test plugs in piping tees.

L. Install flow indicators in piping systems in accessible positions for easy viewing.

M. Install permanent indicators on walls or brackets in accessible and readable positions.

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

O. Install thermometers in the inlet and outlet piping of each:

1. Hydronic zone.
2. Hydronic boiler.
3. Chiller, chilled water and condenser water connection.
4. Air-handling unit hydronic coil.
5. Hydronic heat exchanger.

P. Install pressure gages in the inlet and outlet piping of each:

1. Pressure-reducing valve.
2. Chiller, chilled water water connection.
3. Air handling unit hydronic coil.
4. Pump.
5. Hydronic heat exchanger.
6. Air and/or dirt separators.

Q. Install temperature and pressure test ports at each terminal unit reheat coil.

3.2. ADJUSTING

A. Adjust faces of instruments and gages to proper angle for best visibility.

END OF SECTION

SECTION 23 05 29 – HANGERS AND SUPPORTS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes pipe hangers and hanger shields, metal framing systems, fastener systems, pipe-stands and equipment supports.

1.2. PERFORMANCE REQUIREMENTS

A. Delegated Design: Design trapeze pipe hangers and equipment supports, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

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

1. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.

2. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.

3. Design seismic-restraint hangers and supports for piping and equipment.

1.3. SUBMITTALS

A. Qualification Submittals: Welding certificates.

B. Product Submittals: For each type of product indicated.

1.4. QUALITY ASSURANCE

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

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

PART 2 - PRODUCTS

2.1. METAL PIPE HANGERS AND SUPPORTS

A. Carbon-Steel Pipe Hangers and Supports: MSS SP-58, Types 1 through 58, factory-fabricated components. Hangers shall be galvanized. Padded hangers shall be fiberglass pad or cushion to support bearing surface of piping. Hanger rods shall be continuously threaded with nuts and washers made of carbon steel.

B. Stainless-Steel Pipe Hangers and Supports: MSS SP-58, Types 1 through 58, factory-fabricated components. Padded hangers shall be fiberglass pad or cushion to support bearing surface of piping. Hanger rods shall be continuously threaded with nuts and washers made of stainless steel.

C. Copper Pipe Hangers: MSS SP-58, Types 1 through 58, copper-coated-steel, factory-fabricated components. Hanger rods shall be continuously threaded with nuts and washers made of stainless steel.

2.2. TRAPEZE PIPE HANGERS

A. Description: MSS SP-59, 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. Description: Shop or field-fabricated pipe-support assembly for supporting multiple parallel pipes. Channels shall be continuous slotted steel with in-turned lips. Channel nuts shall be designed to fit into channel slot and when tightened to prevent slipping. Hanger rods shall be continuously threaded with nuts and washers made of carbon steel.

2.4. THERMAL-HANGER SHIELD INSERTS

A. Insulation-Insert Material: ASTM C 552, Type II cellular glass with 100-psig minimum compressive strength. For cold piping systems, include vapor barrier.

B. Insert and shield shall cover the entire pipe circumference for trapeze of clamped systems and cover the lower 180-degrees of pipe circumference for clevis or band hangers.

C. Insert Length: Extend 2 inches beyond sheet metal shield for piping operating below ambient air temperature.

2.5. FASTENER SYSTEMS

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

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.

2.6. EQUIPMENT SUPPORTS

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

2.7. 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, non-shrink and nonmetallic grout; suitable for interior and exterior applications.

1. Design Mix: 5000-psi, 28-day compressive strength.

PART 3 - EXECUTION

3.1. HANGER AND SUPPORT INSTALLATION

A. Metal Pipe-Hanger Installation: Comply with MSS SP-58. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.

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

C. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.

D. Fastener System Installation:

1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.

2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

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 and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.

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, 2 1/2-inches NPS 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. Attach clamps and spacers to piping. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping. Clamps may project through the insulation of hot piping systems. Use thermal hanger shield inserts with clamp sized to match outside diameter of insert for cold piping systems.
2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.
4. Shield Dimensions for Pipe: Not less than the following:
   a. Less than 4-inches NPS: 12-inches long and 0.060-inch thick.
   b. 4 to 6-inches NPS: 18-inches long and 0.060-inch thick.
5. 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 trapeze pipe hangers and equipment supports.

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

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

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

3.4. 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.

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.

B. 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-58 for pipe-hanger selections and applications that are not specified in piping system Sections.

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

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

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

F. Use stainless-steel pipe hangers and stainless-steel attachments for hostile environment applications.

G. Use copper-plated pipe hangers and copper or stainless-steel attachments for copper piping and tubing.

H. Use padded hangers for piping that is subject to scratching.

I. Use thermal-hanger shield inserts for insulated piping and tubing.

J. Horizontal-Piping Hangers and Supports:

1. Adjustable Steel Clevis Hangers (MSS Type 1)

2. Split-Ring Hangers (MSS Type 69): Piping 2-inches NPS and smaller.

3. Copper Pipe Hangers: For copper piping.

K. Trapeze Pipe-Hangers: Trapeze hangers shall be welded carbon steel pre-formed structural members suspended by threaded rods. Comply with MSS SP-58. Each pipe shall be individually supported.

1. Adjustable Pipe Saddles (MSS Type 38)

2. Copper Pipe Saddles: For copper piping.

L. Vertical-Piping Clamps:

1. Riser Clamps (MSS Type 8)

M. Building Attachments: Install MSS compliant devices for all building attachments. Install them per manufacturer’s instructions.

N. Saddles and Shields:

1. Steel-Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.

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

3. Thermal-Hanger Shield Inserts: For supporting insulated pipe.

O. Spring Hangers and Supports:

1. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.

2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches.

3. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.

4. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.

5. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from base support.

6. Variable-Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from trapeze support.

7. Constant Supports: For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types: horizontal (MSS Type 54), vertical (MSS Type 55) or trapeze (MSS Type 56).

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

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

3.7. PIPE HANGER INSTALLATION

A. Steel Piping: Install hangers for steel piping with the following minimum rod sizes and maximum spacing:

1. 1 1/4-inch NPS and smaller: 3/8-inch diameter at 7-foot span.

2. 1 1/2-inch NPS: 3/8-inch diameter at 9-foot span.

3. 2-inch NPS: 3/8-inch diameter at 10-foot span.

4. 2 1/2-inch NPS: 1/2-inch diameter at 10-foot span.
5. 3-inch NPS: 1/2-inch diameter at 12-foot span.
6. 4-inch NPS: 5/8-inch diameter at 12-foot span.
7. 6-inch NPS: 3/4-inch diameter at 12-foot span.
8. 8 to 12-inch NPS: 7/8-inch diameter at 12-foot span.
9. 14 to 16-inch NPS: 1-inch diameter at 12-foot span.
10. 18 to 20-inch NPS: 1 1/4-inch diameter at 12-foot span.
11. 22 to 24-inch NPS: 1 1/2-inch diameter at 12-foot span.

B. Copper Piping: Install hangers for drawn-temper copper piping with the following minimum rod sizes and maximum spacing:

1. 1 1/4-inch NPS and smaller: 3/8-inch diameter at 5-foot span.
2. 1 ½ to 2-inch NPS: 3/8-inch diameter at 8-foot span.
3. 2 1/2-inch NPS: 1/2-inch diameter at 9-foot span.
4. 3-inch NPS: 1/2-inch diameter at 10-foot span.
5. 4-inch NPS: 5/8-inch diameter at 10-foot span.

C. Plastic Piping Hanger Spacing: Space hangers according to pipe manufacturer's written instructions for service conditions. Avoid point loading. Space and install hangers with the fewest practical rigid anchor points.

D. Support vertical runs at roof, at each floor, and at 8-foot intervals between floors.

END OF SECTION

SECTION 23 05 33 – HEAT TRACING

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes heat tracing for HVAC piping with electric heating cables:

1.2. SUBMITTALS

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

B. Close-Out Submittals:

1. Operation and Maintenance Data: For electric heating cables to include in operation and maintenance manuals.

1.3. QUALITY ASSURANCE

A. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

B. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

1.4. WARRANTY

A. Special Warranty: Manufacturer agrees to repair or replace electric heating cable that fails in materials or workmanship within specified warranty period.

1. Warranty Period: Five (5) years from date of Owner Acceptance.

PART 2 - PRODUCTS

2.1. SELF-REGULATING PARALLEL-RESISTANCE HEATING CABLES

A. Comply with IEEE 515.1.

B. Heating Element: Pair of parallel No. 16 AWG, nickel-coated, stranded copper bus wires embedded in cross-linked conductive polymer core, which varies heat output in response to temperature along its length. Terminate with waterproof, factory-assembled, non-heating leads with connectors at one end, and seal the opposite end watertight. Cable shall be capable of crossing over itself once without overheating.

C. Electrical Insulating Jacket: Flame-retardant polyolefin.

D. Cable Cover: Stainless-steel braid and polyolefin outer jacket with ultraviolet inhibitor.

E. Temperature Performance:

1. Piping Systems Operating at maximum 120 deg F:

   a. Maximum Operating Temperature (Power On): 150 deg F.

   b. Maximum Exposure Temperature (Power Off): 185 deg F.

2. Piping Systems Operating at 121 deg F to 211 deg F:

   a. Maximum Operating Temperature (Power On): 230 deg F.

   b. Maximum Exposure Temperature (Power Off): 275 deg F.

F. 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. Coordinate the voltage and phase requirements with the electrical documents.

G. Capacities and Characteristics: Provide the number and rating of heating cables appropriately sized for their intended use but not less than:

1. Piping with 1-inch insulation: (1) 5 W/LF for piping less than 6-inches NPS; (1) 8 W/LF for 6 to 8-inches NPS; (2) 5 W/LF for 10-inches NPS; (2) 8 W/LF for 12 to 18-inches NPS; and (3) 8 W/LF for 20 to 24-inches NPS.

2. Piping with 1.5-inch insulation: (1) 5 W/LF for piping less than 8-inches NPS; (1) 8 W/LF for 8 to 12-inches NPS; (2) 5 W/LF for 14 to 16-inches NPS; and (2) 8 W/LF for 18 to 24-inches NPS.

3. Piping with 2-inches insulation: (1) 5 W/LF for piping less than 10-inches NPS; (1) 8 W/LF for 10 to 16-inches NPS; and (2) 5 W/LF for 18 to 24-inches NPS.

2.2. CONTROLS

A. Operational Controls:

1. Remote bulb unit with adjustable temperature range from 30 to 50 deg F.

2. Snap action; open-on-rise, single-pole switch with minimum current rating adequate for connected cable.

3. Remote bulb on capillary, resistance temperature device, or thermistor for directly sensing pipe-wall temperature.

4. Corrosion-resistant, waterproof control enclosure.

B. Digital Controls:

1. Individual digital alarm signals for loss of power, cable failure and pipe low temperature.

2. Digital control module panel with BACnet or ModBus interface to building automation system. Panel shall have alarm warning lights.

2.3. ACCESSORIES

A. Cable Installation Accessories: Fiberglass tape, heat-conductive putty, cable ties, silicone end seals and splice kits, and installation clips all furnished by manufacturer, or as recommended in writing by manufacturer.

B. Warning Tape: Continuously printed "Electrical Tracing"; vinyl, at least 3 mils thick and minimum 3/4-inch wide with pressure-sensitive, permanent, waterproof, self-adhesive back.

C. Pilot Light: LED pilot light that is energized when the heating elements are energized.

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine surfaces and substrates to receive electric heating cables for compliance with requirements for installation tolerances and other conditions affecting performance.

1. Ensure surfaces and pipes in contact with electric heating cables are free of burrs and sharp protrusions.

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

3.2. INSTALLATION

A. Install heat tracing on all outside above-ground water piping, tanks and water equipment to prevent freezing. Refer to drawings for more information.

B. Install electric heating cable across expansion joints according to manufacturer's written instructions; use slack cable to allow movement without damage to cable.

C. Install electric heating cables after piping has been tested and before insulation is installed.

D. Install electric heating cables according to IEEE 515.1.

E. Install insulation over piping with electric cables according to Section 230719 "HVAC Piping Insulation."

F. If splices are necessary, install such that they are not covered under the pipe insulation.

G. Install warning tape on piping insulation where piping is equipped with electric heating cables.

H. Set field-adjustable switches and circuit-breaker trip ranges.

3.3. CONNECTIONS

A. Ground equipment and connect wiring according to Division 26.

3.4. FIELD QUALITY CONTROL

A. Perform the following tests and inspections:

1. Perform tests after cable installation but before application of coverings such as insulation, wall or ceiling construction, or concrete.

2. Test cables for electrical continuity and insulation integrity before energizing.

3. Test cables to verify rating and power input. Energize and measure voltage and current simultaneously.

B. Repeat tests for continuity, insulation resistance, and input power after applying thermal insulation on pipe-mounted cables.

3.5. PROTECTION

A. Protect installed heating cables, including non-heating leads, from damage during construction.

B. Remove and replace damaged heat-tracing cables.

END OF SECTION

SECTION 23 05 48 – HVAC SEISMIC, WIND AND VIBRATION CONTROLS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes seismic, wind and vibration control devices and related materials, including isolators, mounts, guides and supports.

B. Description: Delegated design of all equipment and materials installed under Division 23.

1. Seismic Bracing: Applies to all HVAC equipment and materials based on the seismic criteria defined in this section.

2. Wind Restraints: Applies to all HVAC equipment and materials installed outdoors, above-grade.

3. Vibration Isolation: Applies to all HVAC equipment and materials.

1.2. SUBMITTALS

A. Delegated-Design Submittals: For each vibration isolation, wind restraint and seismic restraint device:

1. Include design calculations and details for selecting vibration isolators, wind restraints, seismic restraints, and vibration isolation bases complying with performance requirements, design criteria, and analysis data signed and sealed by the qualified professional engineer (registered in the state of the project's location) responsible for their preparation.

2. Design Calculations: Calculate static and dynamic loading due to equipment weight, operation, and seismic and wind forces required to select vibration isolators and seismic and wind restraints and for designing vibration isolation bases.

a. Coordinate design calculations with wind load calculations required for equipment mounted outdoors. Comply with requirements in other Sections for equipment mounted outdoors.

3. Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure, spring deflection changes, and seismic loads. Include certification that riser system was examined for excessive stress and that none exists.

4. Seismic and Wind Restraint Details:

a. Design Analysis: To support selection and arrangement of seismic and wind restraints. Include calculations of combined tensile and shear loads.

b. Details: Indicate fabrication and arrangement. Detail attachments of restraints to the restrained items and to the structure. Show attachment locations, methods and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during seismic events. Indicate association with vibration isolation devices.

c. Coordinate seismic-restraint and vibration isolation details with wind-restraint details required for equipment mounted outdoors. Comply with requirements in other Sections for equipment mounted outdoors.

B. Product Submittals: For each type of product indicated.

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

2. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of vibration isolation, wind restraint and seismic restraint device required.

1.3. QUALITY ASSURANCE

A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is an NRTL as defined by OSHA in 29 CFR 1910.7 and that is acceptable to authorities having jurisdiction.

B. Comply with seismic-restraint requirements in the Virginia Construction Code unless requirements in this Section are more stringent.

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

D. Seismic-restraint devices shall have horizontal and vertical load testing and analysis and shall bear anchorage preapproval OPA number from OSHPD, preapproval by an agency acceptable to authorities having jurisdiction, showing maximum seismic-restraint ratings. Ratings based on independent testing are preferred to ratings based on calculations. If preapproved ratings are unavailable, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) to support seismic-restraint designs must be signed and sealed by a qualified professional engineer.

PART 2 - PRODUCTS

2.1. MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide product by one of the following for spring and elastomeric isolators:

1. Mason Industries, Inc.

2. Kinetics Noise Control, Inc.

3. Vibration Eliminator Company, Inc.

4. Vibration Mounting & Controls (VMC) Group, Inc.

2.2. PERFORMANCE REQUIREMENTS

A. Wind-Restraint Loading:

1. Ultimate Wind Speed: 120 MPH.

2. Building Risk Category: IV.

3. Minimum 50 lb/sq. ft. multiplied by maximum area of HVAC component projected on vertical plane normal to wind direction, and 45 degrees either side of normal.

B. Seismic-Restraint Loading:

1. Site Class as Defined in the State Building Code: D (Assumed).

2. Seismic Design Category: C.

3. Assigned Risk Category as Defined in the State Building Code: IV.

a. Component Importance Factor of 1.5:

1) Smoke Control Systems including Make-Up Air Systems

2) Life-Safety Dampers

3) Natural Gas, Propane (LP) Gas, and Fuel Oil Piping Systems

4) Carbon Monoxide Detection and Alarm Systems

5) Fuel-Fired Equipment Chimneys and Breechings

6) HVAC Systems in First Responder Facilities (Law Enforcement, EMT, Fire, Rescue and 911 Emergency Call Centers)

b. Component Importance Factor of 1.0: All other systems and their components.

c. Component Response Modification Factor: Table 13.6-1, ASCE 7-16 - Chapter 13.

d. Component Amplification Factor: Table 13.6-1, ASCE 7-16 - Chapter 13.

4. Design Spectral Response Acceleration at Short Periods (0.2 Second): 0.258.

5. Design Spectral Response Acceleration at 1.0-Second Period: 0.113.

6. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they are subjected.

C. Seismic Performance: HVAC equipment shall withstand the effects of earthquake motions determined according to ASCE/SEI-16. The term “withstand” means the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified.

D. Critical Functions: In addition, the following equipment and systems shall be fully operational after the seismic event:

1. Computer room air-conditioners serving data centers and emergency communications equipment.

2.3. ELASTOMERIC ISOLATION PADS

A. Description: Elastomeric Isolation Pads.

1. Fabrication: Single or multiple layers of sufficient durometer stiffness for uniform loading over pad area.

2. Size: Factory or field cut to match requirements of supported equipment.

3. Pad Material: Oil and water resistant with elastomeric properties.

4. Surface Pattern: Waffle pattern.

5. Infused nonwoven cotton or synthetic fibers.

6. Load-bearing metal plates adhered to pads.

7. Sandwich-Core Material: Resilient and elastomeric.

    a. Surface Pattern: Waffle pattern.

    b. Infused nonwoven cotton or synthetic fibers.

2.4. ELASTOMERIC ISOLATION MOUNTS

A. Description: Double-Deflection, Elastomeric Isolation Mounts.

1. Mounting Plates:

    a. Top Plate: Encapsulated steel load transfer top plates, factory drilled and threaded with threaded studs or bolts.

    b. Baseplate: Encapsulated steel bottom plates with holes provided for anchoring to support structure.

2. Elastomeric Material: Molded, oil-resistant rubber, neoprene, or other elastomeric material.

2.5. RESTRAINED ELASTOMERIC ISOLATION MOUNTS

A. Description: All-directional isolator with seismic restraints containing two separate and opposing elastomeric elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.

1. Housing: Cast-ductile iron or welded steel.

2. Elastomeric Material: Molded, oil-resistant rubber, neoprene, or other elastomeric material.

2.6. OPEN SPRING ISOLATORS

A. Description: 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 steel plate for bolting to structure with an elastomeric isolator pad attached to the underside. Baseplates shall limit floor load to 500 psig.

6. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

2.7. HOUSED SPRING ISOLATORS

A. Description: Freestanding, Laterally Stable, Open-Spring Isolators in Two-Part Telescoping Housing.

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. Two-Part Telescoping Housing: A steel top and bottom frame separated by an elastomeric material and enclosing the spring isolators.

   a. Drilled base housing for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig.

2.8. RESTRAINED SPRING ISOLATORS

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

1. Housing: Steel housing with vertical-limit stops to prevent spring extension due to weight being removed.

   a. Base with holes for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig.

   b. Top plate with threaded mounting holes or elastomeric pad.

   c. Internal leveling bolt that acts as blocking during installation.

2. Restraint: Limit stop as required for equipment and authorities having jurisdiction.

3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.

4. Minimum Additional Travel: 50 percent of the required deflection at rated load.

5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.

6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

2.9. HOUSED RESTRAINED SPRING ISOLATORS

A. Description: Freestanding, Steel, Open-Spring Isolators with Vertical-Limit Stop Restraint in Two-Part Telescoping Housing.

1. Two-Part Telescoping Housing: A steel top and bottom frame separated by an elastomeric material and enclosing the spring isolators. Housings are equipped with adjustable snubbers to limit vertical movement.

    a. Drilled base housing for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig.

    b. Threaded top housing with adjustment bolt and cap screw to fasten and level equipment.

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.

2.10. PIPE RISER RESILIENT SUPPORTS

A. Description: All-directional, acoustical pipe anchor consisting of two steel tubes separated by a minimum 1/2-inch thick neoprene.

1. Vertical-Limit Stops: Steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions.

2. Maximum Load Per Support: 500 psig on isolation material providing equal isolation in all directions.

2.11. RESILIENT PIPE GUIDES

A. Description: Telescopic arrangement of two steel tubes or post and sleeve arrangement separated by a minimum 1/2-inch-thick neoprene.

1. Factory-Set Height Guide with Shear Pin: Shear pin shall be removable and re-insertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

2.12. ELASTOMERIC HANGERS

A. Description: Elastomeric Mount in a Steel Frame with Upper and Lower Steel Hanger Rods.

1. Frame: Steel, fabricated with a connection for an upper threaded hanger rod and an opening on the underside to allow for a maximum of 30 degrees of angular lower hanger-rod misalignment without binding or reducing isolation efficiency.

2. Dampening Element: Molded, oil-resistant rubber, neoprene, or other elastomeric material with a projecting bushing for the underside opening preventing steel to steel contact.

2.13. SPRING HANGERS

A. Description: 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. Adjustable Vertical Stop: Steel washer with neoprene washer "up-stop" on lower threaded rod.

8. Self-centering hanger-rod cap to ensure concentricity between hanger rod and support spring coil.

2.14. SNUBBERS

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

1. Anchor bolts for attaching to concrete shall be seismic-rated, drill-in, and stud-wedge or female-wedge type.

2. Resilient Isolation Washers and Bushings: Oil- and water-resistant neoprene.

3. Maximum 1/4-inch air gap, and minimum 1/4-inch-thick resilient cushion.

2.15. RESTRAINT CHANNEL BRACINGS

A. Description: MFMA-4, shop- or field-fabricated bracing assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end and other matching components and with corrosion-resistant coating; rated in tension, compression, and torsion forces.

2.16. RESTRAINT CABLES

A. Restraint Cables: ASTM A 492 stainless-steel cables. End connections made of steel assemblies with thimbles, brackets, swivel, and bolts designed for restraining cable service; with a minimum of two clamping bolts for cable engagement.

2.17. SEISMIC RESTRAINT ACCESSORIES

A. Hanger-Rod Stiffener: Steel tube or steel slotted-support-system sleeve with internally bolted connections to hanger rod.

B. Hinged and Swivel Brace Attachments: Multifunctional steel connectors for attaching hangers to rigid channel bracings and restraint cables.

C. Bushings for Floor-Mounted Equipment Anchor Bolts: Neoprene bushings designed for rigid equipment mountings and matched to type and size of anchor bolts and studs.

D. Bushing Assemblies for Wall-Mounted Equipment Anchorage: Assemblies of neoprene elements and steel sleeves designed for rigid equipment mountings and matched to type and size of attachment devices used.

E. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.

2.18. MECHANICAL ANCHOR BOLTS

A. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

2.19. ADHESIVE ANCHOR BOLTS

A. Adhesive Anchor Bolts: Drilled-in and capsule anchor system containing PVC or urethane methacrylate-based resin and accelerator, or injected polymer or hybrid mortar adhesive. Provide anchor bolts and hardware with zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine areas and equipment to receive vibration isolation and seismic and wind control devices for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

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

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

3.2. APPLICATIONS

A. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application.

B. Hanger-Rod Stiffeners: Install hanger-rod stiffeners where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods due to seismic forces.

C. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select sizes of components so strength is adequate to carry present and future static and seismic loads within specified loading limits.

D. Vibration Isolation: In addition to vibration isolation devices indicated within the project documents, provide isolators per ASHRAE Handbook – "HVAC Applications", Chapter 49, Table 47 "Selection Guide for Vibration Isolation".

1. Install vibration isolators on all vibrating equipment.

2. Suspended Piping: Install vibration isolation hangers in all mechanical equipment rooms and on all piping within 50 feet of vibrating equipment connections.

   a. Three hangers closest to each equipment connection shall be rated for deflection equal to the equipment isolator deflection.

   b. The remaining hangers shall have a deflection of 3/4-inch.

   c. Exceptions: Not required at terminal equipment connections where the equipment is isolated, such as terminal units, blower coil units, fan coil units and heaters.

3.3. CONTROL AND RESTRAINT DEVICE INSTALLATION

A. Coordinate the location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork.

B. Installation of vibration isolators must not cause any change of position of equipment, piping, or ductwork resulting in stresses or misalignment.

C. Equipment Restraints:

1. Install seismic snubbers on HVAC equipment mounted on vibration isolators. Locate snubbers as close as possible to vibration isolators and bolt to equipment base and supporting structure.

2. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.

3. Install seismic-restraint devices.

D. Piping Restraints:

1. Comply with requirements in MSS SP-127.

2. Space lateral supports a maximum of 40 feet o.c., and longitudinal supports a maximum of 80 feet o.c.

3. Brace a change of direction longer than 12 feet.

E. Install cables so they do not bend across edges of adjacent equipment or building structure.

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

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

H. 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.

I. 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 pre-stressed 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.

3.4. ACCOMODATION OF DIFFERENTIAL SEISMIC MOTION

A. Install flexible connections in piping where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where the connections terminate with connection to equipment that is anchored to a different structural element from the one supporting the connections as they approach equipment. Comply with requirements in Section 232113 for piping flexible connections.

3.5. FIELD QUALITY CONTROL

A. Perform tests and inspections:

1. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.

2. Schedule test with Owner, through Architect, before connecting anchorage device to restrained component (unless post-connection testing has been approved), and with at least seven days' advance notice.

3. Obtain Architect's approval before transmitting test loads to structure. Provide temporary load-spreading members.

4. Test at least four of each type and size of installed anchors and fasteners selected by Engineer.

5. Test to 90 percent of rated proof load of device.

6. Measure isolator restraint clearance.

7. Measure isolator deflection.

8. Verify snubber minimum clearances.

B. Remove and replace malfunctioning units and retest as specified above.

C. Prepare test and inspection reports.

3.6. ADJUSTING

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

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

END OF SECTION

SECTION 23 05 53 – HVAC SYSTEMS IDENTIFICATION

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes equipment, pipe and duct labels and tags.

1.2. SUBMITTALS

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

1. Product Data: For each type of product indicated.
2. Samples: For color, letter style, and graphic representation required for each identification material and device.

B. Close-Out Submittals:

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

1.3. COORDINATION

A. Coordinate the identification requirements with the Owner's up-to-date standards prior to purchasing materials.

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

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

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

PART 2 - PRODUCTS

2.1. EQUIPMENT LABELS

A. Plastic Labels for Equipment: 1/8-inch multilayer, multicolor, plastic labels for mechanical engraving suitable for temperatures up to 160 deg F with pre-drilled holes for stainless steel rivets or self-tapping screws. Labels shall be minimum 2-1/2 inches wide and 3/4-inch tall with 3/8-inch white letters on black background.

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

B. Label Content: Include equipment's drawing designation or unique equipment number.

2.2. WARNING SIGNS AND LABELS

A. Warning Signs and Labels: 1/8-inch multilayer, multicolor, plastic labels for mechanical engraving suitable for temperatures up to 160 deg F with pre-drilled holes for stainless steel rivets or self-tapping screws. Labels shall be minimum 2-1/2 inches wide and 3/4-inch tall with 3/8-inch letters.

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

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

2.3. PIPE LABELS

A. Pipe Labels: Pre-printed, color-coded, self-adhesive vinyl labels with lettering and flow direction arrows. They shall have minimum 1 1/2-inch tall block lettering. The labels shall be suitable for temperatures up to 160 deg F and compatible with each substrate material.

2.4. DUCT LABELS

A. Duct Labels: Pre-printed, color-coded, self-adhesive vinyl labels with lettering and flow direction arrows. They shall have minimum 1 1/2-inch tall block lettering. The labels shall be suitable for temperatures up to 160 deg F and compatible with each substrate material.

2.5. STENCILS

A. Stencils: Prepared with letter sizes according to ASME A13.1 for piping; minimum letter height of 1-1/4 inches for ducts; 3/4-inch for rated penetrations, and minimum letter height of 3/4 inch for access panel and door labels, equipment labels, and similar operational instructions. Stencil paint shall be exterior, gloss, acrylic enamel.

2.6. VALVE TAGS

A. Valve Tags: 0.032-inch thick brass or 0.025-inch thick stainless steel, stamped or engraved, with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers with pre-drilled or stamped holes for beaded chain or S-hook attachment hardware.

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

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

2.7. CEILING TAGS

A. Ceiling tags shall consist of a color marker and a printed identification label used to specify what the color marker is locating. Printed labels shall be installed adjacent to the associated color marker.

1. Ceiling Grid Markers: Color grid markers shall be 7/8-inch diameter, 10-mil thick, vinyl or polypropylene with self-stick adhesive backing. Grid markers shall be the color as indicated below.

a. Neon Yellow Sticker: Mechanical-Equipment/Dampers, etc.

b. Yellow Sticker: Gas – Valves/Regulators, etc.

c. Blue Sticker: Chilled Water-Valves, etc. / Domestic CW-Valves/Arrestor, etc.

d. Green Sticker: Heating Hot Water-Valves, etc. / Domestic HW-Valves, etc.

e. Neon Red Sticker: Electrical – Pull Box/Future/Disconnects, etc.

f. Red Sticker: Fire Alarm/Life Safety

2. Ceiling Identification Labels: Ceiling tag labels shall be no more than 1-inch in height, vinyl or polypropylene with self-stick adhesive backing. Lettering shall be black on white tape with minimum 18-point font. Labels may be created with a portable printer such as Brady HandiMark Portable Industrial Labeling System or equal.

2.8. WARNING TAGS

A. Warning Tags: 5-1/4 inches wide and 3-inches tall, pre-printed or partially pre-printed, accident-prevention tags, of plasticized card stock with matte finish suitable for writing, fastened with reinforced grommet and wire. Tags shall have letters with large-size primary caption such as "DANGER," "CAUTION," or "DO NOT OPERATE."

2.9. SENSOR TAGS

A. Sensor Tags: 1/4-inch wide, pre-printed, clear vinyl adhesive tags with 1/8-inch tall block-letter black text. Each sensor shall be clearly and neatly labelled. Tags shall denote the associated piece of equipment, for example “TU-123”.

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 encapsulates.

3.2. JACKET COLOR

A. Piping and Piped Equipment Insulation Jacket: Paint or provide pre-colored jacketing for all piping system insulation jacketing meeting the requirements of this section.

1. P/M/E Equipment Rooms: Color per System Identification Schedule.

2. Exposed-to-View: White.

3. Concealed: Not required.

B. Duct and Ducted Equipment Insulation Jacket: Paint or provide pre-colored jacketing for all duct system insulation jacketing meeting the requirements of this section.

1. PME Equipment Rooms: Color per System Identification Schedule.

2. Exposed-to-View: White.

3. Concealed: Not required.

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 25 feet along each run. Reduce intervals to 10 feet in areas of congested piping and equipment.
7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

3.4. EQUIPMENT LABEL INSTALLATION

A. Install or permanently fasten labels on each major item of mechanical equipment. Equipment to be labelled includes but is not limited to:

1. Air handling equipment, including AHU, BCU, FCU, RTU, DOAS, ERU, CRAC, etc.
2. Fans.
3. Terminal units.
4. Heating and cooling coils.
5. Condensing units.
6. Split-systems.
7. Hydronic equipment, including pumps, water treatment, tanks and separators.
8. Boilers.
9. Chillers.
10. Unit heaters.
11. Flow and energy meters.
12. Control panels and main sensors.
13. Variable speed controllers, motor starters and disconnects.
    a. Coordinate labeling with Division 26.

B. Central HVAC system equipment labels shall include capacity and design information. Submit proposed label information for Engineer approval. The following are examples:

1. Chillers

CHILLER CH-1
INSTALLED: JUNE 2030
CAPACITY: 500 TONS
CHW FLOW: 1200 GPM
CDW FLOW: 1500 GPM

2. Boilers

BOILER B-1
INSTALLED: JUNE 2030
OUTPUT: 1600 MBH
INPUT: 2000 MBH
HHW FLOW: 160 GPM
HHW TEMPS: 160F / 180F

3. Air Handling Units

AIR HANDLING UNIT AHU-1
INSTALLED: JUNE 2030
SERVICE: CLASSROOM WING A
CAPACITY: 10,000 CFM at 2.0" ESP
COOLING: 25 TONS
HEATING: 400 MBH

4. Fans

EXHAUST FAN EF-1
INSTALLED: JUNE 2030
SERVICE: ROOM 201 FUME HOOD
CAPACITY: 500 CFM at 0.5" ESP

C. Locate equipment labels where accessible and visible.

D. Equipment Color Schedule: Insulation color and label scheme shall match the associated piping system.

3.5. DUCT LABEL INSTALLATION

A. Duct Labels: Install self-adhesive duct labels with permanent adhesive on air ducts.

1. Stenciled Duct Label Option: Stenciled labels, showing service and flow direction, may be provided instead of plastic-laminated duct labels, at Installer's option, if lettering larger than 1-inch high is needed for proper identification because of distance from normal location of required identification.

B. Locate labels near points where ducts enter into concealed spaces and at maximum intervals of 25 feet in each space where ducts are exposed or concealed by removable ceiling system.

3.6. 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.

3.7. CEILING TAG INSTALLATION

A. Provide ceiling tags, consisting of a color grid marker and printed label, for each item above finished ceilings, including all items requiring access such as equipment, valves, dampers, devices, and other elements of the work. Install printed labels directly adjacent to their associated color marker.

B. Install ceiling tags on lay-in grid runners and access doors directly below the associated item. Center color markers and printed labels on grid members and doors.

3.8. WARNING-TAG INSTALLATION

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

3.9. SENSOR TAG INSTALLATION

A. Install sensor tags for wall or ceiling-mounted sensors on faceplates centered below the device. Install sensor tags for concealed sensors on sensor enclosures or backboxes. Where sensors are located above lay-in ceilings, behind access doors, or otherwise remotely accessible, label the grid or door in addition to the device itself. Tags shall be centered and neatly applied.

3.10. RATED PENETRATION INSTALLATION

A. Stencil penetration ratings and UL detail numbers on wall surfaces directly adjacent to the penetrations. UL detail number shall match the material used. This information shall be readily visible in non-occupied spaces, within chases and above ceilings. The following is an example:

2-HR RATED FIRE BARRIER
UL DETAIL SYSTEM NO. ABC-0000

3.11. SYSTEM IDENTIFICATION SCHEDULE

A. Install equipment, piping and duct identification materials with the color and abbreviations that match the Owner’s standard practice. Refer to System Identification Schedule below.

SYSTEM IDENTIFICATION SCHEDULE			
PIPING SYSTEMS	ABBREV.	BACKGROUND	LETTERING
CHILLED WATER	CHWS/CHWR	DARK BLUE	WHITE
REFRIGERANT	REF	WHITE	BLACK
DOMESTIC WATER	DCW/DHW/DHWR	GREEN	WHITE
NON-POTABLE WATER	NPW	LIGHT GRAY	WHITE
CONDENSATE DRAIN	CD	WHITE	BLACK
HEATING WATER	HWS/HWR	DARK RED	WHITE
PROPANE GAS	LPG	YELLOW	BLACK
OTHERS	SEE PLANS	WHITE	BLACK
VALVE TAGS		BRASS	BLACK
EQUIPMENT AND DUCT SYSTEMS	ABBREV.	BACKGROUND	LETTERING
GENERAL BUILDING AIR	SA/RA/EA/OA	WHITE	BLACK
WARNING SIGNS	SEE PLANS	SAFETY YELLOW	BLACK
EQUIPMENT TAGS	SEE PLANS	BLACK	WHITE

NOTE: PROVIDE FLOW ARROWS ON ALL DUCT AND PIPE MARKERS.

END OF SECTION

SECTION 23 05 55 – HVAC PIPING SYSTEMS FLUSHING AND TESTING

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes requirements for HVAC piping system flushing and testing.

1.2. SUBMITTALS

A. Delegated Design Submittals:

1. Flushing and Testing Plan: Submit a Flushing and Testing Plan for review and approval of the Engineer prior to the start of work. The plan shall include proposed use of building and any temporary equipment; extent of piping system to be flushed and tested in each phase, if not performed all at once; flushing sequence timetable with approximate durations; source of water; disposal of water; flow rates; any temporary bypass details; chemical MSDS; etc.

B. Product Submittals: For each type of product indicated include rated capacities, operating characteristics, and furnished specialties and accessories.

C. Construction Submittals:

1. Flushing and Testing Field Reports: For each section of piping that is independently flushed and tested, provide a letter to the Engineer certifying that the flushing and testing was performed in accordance with the requirements; documenting the failures and corrective actions taken; and recording the final results. Each letter shall be signed and dated by the Mechanical Contractor's Representative who performed the tests and the General Contractor' Representative who witness the tests certifying the piping system is clean and leak-free. A plan of the piping systems with sections flushed and tested highlighted shall be attached to each letter. The flushing and testing schedule shall be coordinated with the Owner and Engineer.

D. Close-Out Submittals:

1. Flushing and Testing Summary: Submit a copy of the Flushing and Testing Plan with any changes required by field conditions; a copy of each Flushing and Testing Field Report; and a Final Flushing and Testing Field Report that certifies that all applicable sections of each piping system have been satisfactorily completed.

PART 2 - PRODUCTS

2.1. TEMPORARY EQUIPMENT AND MATERIALS

A. Provide any temporary equipment and materials required to perform the flushing and testing procedures.

1. Use of existing building pumps prior to their demolition is allowed.

2. Use of new building pumps is prohibited.

B. Temporary materials shall match the permanent materials unless a substitution is approved by the Engineer.

1. Exception: Stainless steel corrugated flexible hoses with stainless steel braided covers rated for pressures in excess of the test pressures may be used for 2-inch and smaller temporary piping bypasses. Hoses must be free of kinks and sharp bends that could prevent proper circulation or restrict flushing of debris.

PART 3 - EXECUTION

3.1. TEMPORARY CONNECTIONS

A. New Heating and Cooling Equipment: At each heating and cooling equipment connection, provide a bypass to isolate the equipment and associated control and balancing valves from the piping.

1. Upon completion of the piping mains and branches up to and including the equipment isolation valves; prior to installing the equipment control and balancing valve assemblies; and prior to installing the pipe insulation, install temporary bypass piping from the supply to the return branches. The bypass shall be of the same size and material as the branch piping. When open, the isolation valves shall allow the flushing and testing procedures. When closed, the isolation valves shall allow the bypass piping to be removed without exposing the completed piping sections.

B. Maintain isolation between accepted and unaccepted piping at all times. If accepted piping is exposed to water circulated through unaccepted piping or any other dirt and debris, then the affected sections shall be re-flushed and tested as determined by the Engineer.

C. If accepted piping is modified, then the affected sections shall be re-flushed and tested.

3.2. HYDRONIC PIPING SYSTEM FLUSHING AND TESTING PROCEDURES

A. Prior to start, verify weld inspections and testing is complete as required in Section 230100.

B. Initial Flushing:

1. Install temporary equipment and piping required to perform flushing.

2. Fill piping system with clean water and vent air.

3. Install initial basket screens in circulation pump strainer. Circulate water and clean out strainer periodically until the initial basket screen remains clean for 30 minutes minimum. Insert final fine grit basket screen. Circulate water and clean out strainer periodically until the final basket screen remains clean for 30 minutes minimum.

4. Upon completion of initial flushing, drain water to sanitary sewer and replace strainer basket screens.

C. Pressure and Leak Testing:

1. Conduct pressure and leak testing after the initial flushing and prior to the final flushing of the system.

2. Conduct pressure and leak testing prior to insulating the piping.

3. Prior to testing, verify the maximum test pressure and duration of piping system components with their manufacturer. Do not test piping systems at pressures and durations in excess of the manufacturer’s recommendations.

4. Prepare hydronic piping for testing according to ASME B31.9 and as follows:

    a. Leave joints, including welds, uninsulated and exposed for examination during test.

    b. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.

    c. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.

    d. 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.

    e. 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.

    f. Fill piping system with clean water.

    g. Remove air from the piping using air vents at all high points in the system. Where air vents have not been installed yet because the final high point will be a part of the equipment valve assembly and connection piping, install manual air vent at the highest point in the temporary bypass piping.

    h. Isolate expansion tanks and determine that hydronic system is full of water.

D. Perform the following tests on hydronic piping:

1. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's maximum working pressure but not less than 100 psig. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."

    a. Refer to Section 232113 and 232133 for hydronic and makeup water piping system operating pressures.

2. After hydrostatic test pressure has been applied for at least 15 minutes, examine piping, joints, and connections for leakage. Eliminate leaks and repeat hydrostatic test until there are no leaks for a continuous 4 hours.

    a. Verify the test pressure does not drop over the duration of the test. Do not perform tests when the ambient temperature rises or drops enough to affect the test pressure.

b. If the piping fails, identify the leakage points, cut out the non-compliant sections and replace them with new materials. Do not attempt to patch, epoxy or caulk leaks.

3. Record results.

4. Upon completion of testing, drain water to sanitary sewer. Use drains installed at low points for complete draining of test liquid.

5. Prepare written report of testing.

6. Upon completion of testing, insulating work may begin.

E. Cleaning and Final Flushing:

1. Fill piping system with clean water and vent air.

2. Add pre-cleaning chemical solution designed to remove construction deposits such as pipe dope, oils, loose scale and other materials at manufacturer's recommended ratios. Circulate for 4 hours minimum and drain to sanitary sewer. Refill and re-flush until the system water is within the following tolerances of the makeup (utility service) water:

a. Alkalinity: 0.3 pH

b. Conductivity: 20 micro-ohms

c. No visible signs of cleaner or contaminates.

3. Fill piping system with clean water and vent air.

4. Add cleaning solution diluted at manufacturer's recommended ratios to effectively clean the piping surfaces but avoid decay of the surface materials. Cleaners with trisodium phosphate are prohibited. Neutralizer agents as recommended by the cleaner manufacturer shall be used.

5. Circulate water and clean out strainer periodically until the basket screen remains clean for 24 hours minimum.

6. Upon completion of final flushing and cleaning, drain water to sanitary sewer.

7. Refill with clean water, vent air and circulate water for 1 hour minimum. Drain water to sanitary sewer.

8. Refill with clean water and treat per Section 232500.

a. If the piping will be isolated from the system for more than 7 days, add corrosion inhibitor, NALCO 3DT279 or equal.

b. If the piping system will be connected to a central utility distribution system, then coordinate the final fill and chemical treatment with the Owner.

9. Remove temporary equipment and piping.

END OF SECTION

SECTION 23 05 93 – TESTING, ADJUSTING AND BALANCING

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes testing, adjusting and balancing (TAB) of building systems.

1.2. GENERAL DESCRIPTION

A. HVAC Air Systems:

1. Verify duct leakage tests and results.

2. TAB of new HVAC air systems including supply, return, exhaust, relief and outside air to design requirements.

B. HVAC Piping Systems:

1. Verify pipe leakage tests and results.

2. TAB of new HVAC piping systems including heating, chilled and heating hot water, and refrigerant to design requirements.

C. HVAC Control Systems:

1. Verify existing-to-remain HVAC control systems that will be reconnected to the new BAS.

2. Verify new HVAC control systems.

D. Vibration Testing:

1. Vibration levels of vibration sensitive spaces (auditorium, electron microscopes, medical equipment).

1.3. SUBMITTALS

A. Qualification Submittals:

1. Qualification Data: Within 30 days of the Notice to Proceed, submit documentation that the TAB contractor and the project's TAB team members meet the qualifications specified in "Quality Assurance".

2. Instrument calibration reports, to include the following: instrument type and make; serial number; application; dates of use; and dates of calibration.

B. Product Submittals: For each type of product indicated.

C. Construction Submittals:

1. Initial certified TAB reports of individual systems for engineer’s review.

2. Commissioning Agent Certification: Provide owner's commissioning agent's certification that TAB measurements have been sampled and are considered accurate.

D. Close-Out Submittals: Final certified TAB report with all systems in a single report.

1.4. QUALITY ASSURANCE

A. TAB Contractor Qualifications: Engage a TAB entity certified by the Associated Air Balance Council (AABC).

1. TAB Field Supervisor: TAB contractor employee who is certified by AABC.

2. TAB Technician: TAB contractor employee who is certified by AABC.

B. TAB Conference: Meet with engineer, owner, construction manager, owner's commissioning agent and related sub-contractors regarding the 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 30-day 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. TAB Certification: 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 AABC report forms as reviewed by the engineer.

E. TAB Instrumentation: Provide instrumentation certification report including equipment type and make, serial number, accuracy and calibration as described in ASHRAE-111, Section 5, "Instrumentation."

1. All instruments shall be calibrated within 6 months of use.

F. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing" and ASHRAE 90.1, Section 6.7.2.3 - "System Balancing".

G. Code and AHJ Compliance: Comply with governing codes and requirements of authorities having jurisdiction.

1.5. PROJECT CONDITIONS

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

1.6. COORDINATION

A. Notice: Provide 10-day notice for each test. Include scheduled test dates and times.

B. Perform TAB after leakage and pressure tests on air and hydronic systems have been satisfactorily completed. Alterations of the systems due to incomplete or non-conforming work made after testing will void previous TAB results and require new testing at no additional cost to the owner or engineer. Verify related work is complete before starting.

1. Duct pressure tested without duct accessories such as dampers and access doors installed is not valid.

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 and underfloor air plenums used for supply, return, or relief air to verify that they meet the leakage class of connected 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. Examine control dampers for proper installation for their intended function of isolating, throttling, di-verting, or mixing air flows.

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

3.2. PREPARATION

A. Prepare a TAB plan that includes strategies and step-by-step procedures including a list of each piece of equipment and system.

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

1. General:

a. Permanent electrical-power wiring is complete.

b. Automatic temperature-control systems are operational.

c. Equipment and duct access doors are securely closed.

d. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.

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

2. HVAC Air Systems:

a. Verify that leakage and pressure tests on air distribution systems have been satisfactorily completed.

b. Duct systems are complete with terminals installed.

c. Volume, smoke, and fire dampers are open and functional.

d. Clean filters are installed.

e. Fans are operating, free of vibration, and rotating in correct direction.

f. Variable-frequency controllers startup is complete and safeties are verified.

g. Automatic temperature-control systems are operational.

h. Ceilings are installed.

i. Windows and doors are installed.

j. Suitable access to balancing devices and equipment is provided.

3. HVAC Piping Systems:

a. Verify leakage and pressure tests on water distribution systems have been satisfactorily completed.

b. Piping is complete with terminals installed.

c. Water treatment is complete.

d. Systems are flushed, filled, and air purged.

e. Strainers are pulled and cleaned.

f. Control valves are functioning in accordance with the sequence of operation.

g. Shutoff and balance valves have been verified to be 100 percent open.

h. Pumps are started and proper rotation is verified.

i. Pump gauge connections are installed directly at pump inlet and outlet flanges or in discharge and suction pipe prior to valves or strainers.

j. Variable-frequency controllers startup is complete and safeties are verified.

k. Suitable access to balancing devices and equipment is provided.

3.3. GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in ASHRAE-111 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 Section 233300.

2. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to specifications.

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. Coordinate pullies and sheaves needed to balance applicable air systems with fan supplier. Refer to Section 233400.

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

F. 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.

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

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

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

J. Check for airflow blockages.

K. Check condensate drains for proper connections and functioning.

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

M. Verify that air duct system is sealed as specified.

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.

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. 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.

E. Verify final system conditions:

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

3.6. 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. Minimum airflow shall be not be below the minimum airflow requirements of the system for proper operation. 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. Re-measure 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.

C. Pressure-Dependent, Variable-Air-Volume Systems without Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Balance variable-air-volume systems the same as described for constant-volume air systems.

2. Set terminal units and supply fan at full-airflow condition.

3. Adjust inlet dampers of each terminal unit to indicated airflow and verify operation of the static-pressure controller. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.

4. Readjust fan airflow for final maximum readings.

5. Measure operating static pressure at the sensor that controls the supply fan if one is installed and verify operation of the static-pressure controller.

6. Set supply fan at minimum airflow if minimum airflow is indicated. Measure static pressure to verify that it is being maintained by the controller.

7. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Minimum airflow shall be not be below the minimum airflow requirements of the system for proper operation. 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 the outlets balanced for maximum airflow.

8. Measure 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.

D. Pressure-Dependent, Variable-Air-Volume Systems with Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set system at maximum indicated airflow by setting the required number of terminal units at minimum airflow. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.

2. Adjust supply fan to maximum indicated airflow with the variable-airflow controller set at maximum airflow.

3. Set terminal units at full-airflow condition.

4. Adjust terminal units starting at the supply-fan end of the system and continuing progressively to the end of the system. Adjust inlet dampers of each terminal unit to indicated airflow. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.

5. Adjust terminal units for minimum airflow. Minimum airflow shall be not be below the minimum airflow requirements of the system for proper operation.

6. Measure static pressure at the sensor.

7. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

E. Single-Zone, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Balance variable-air-volume systems the same as described for constant-volume air systems.

2. Set supply fan at minimum airflow if minimum airflow is indicated. Minimum airflow shall be not be below the minimum airflow requirements of the system for proper operation.

3. 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 the outlets balanced for maximum airflow.

4. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

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

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.

D. Measure and record upstream and downstream pressure of each piece of equipment.

E. Measure and record upstream and downstream pressure of pressure-reducing valves.

F. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.

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

3.8. PROCEDURES FOR CONSTANT-FLOW HYDRONIC SYSTEMS

A. Adjust pumps to deliver total design flow.

1. Measure total water flow.
   a. Position valves for full flow through coils.
   b. Measure flow by main flow meter, if installed.
   c. If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.
2. Measure pump TDH as follows:
   a. Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
   b. Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
   c. Convert pressure to head and correct for differences in gauge heights.
   d. Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
   e. With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to re-duce excess throttling.
3. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.

B. Adjust flow-measuring devices installed in mains and branches to design water flows.

1. Measure flow in main and branch pipes.

2. Adjust main and branch balance valves for design flow.

3. Re-measure each main and branch after all have been adjusted.

C. Adjust flow-measuring devices installed at terminals for each space to design water flows.

1. Measure flow at terminals.

2. Adjust each terminal to design flow.

3. Re-measure each terminal after it is adjusted.

4. Position control valves to bypass the coil and adjust the bypass valve to maintain design flow.

5. Perform temperature tests after flows have been balanced.

D. For systems with pressure-independent valves at terminals:

1. Measure differential pressure and verify that it is within manufacturer's specified range.

2. Perform temperature tests after flows have been verified.

E. For systems without pressure-independent valves or flow-measuring devices at terminals:

1. Measure and balance coils by either coil pressure drop or temperature method.

2. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

F. Verify final system conditions as follows:

1. Re-measure and confirm that total water flow is within design.

2. Re-measure final pumps' operating data, TDH, volts, amps, and static profile.

3. Mark final settings.

G. Verify that memory stops have been set.

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.

B. Adjust the variable-flow hydronic system as follows:

1. Verify that the pressure-differential sensor(s) is located as indicated.

2. Determine whether there is diversity in the system.

C. For systems with no flow diversity:

1. Adjust pumps to deliver total design flow.

a. Measure total water flow.

1) Position valves for full flow through coils.

2) Measure flow by main flow meter, if installed.

3) If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.

b. Measure pump TDH as follows:

1) Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.

2) Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strain-ers.

3) Convert pressure to head and correct for differences in gauge heights.

4) Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.

5) With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.

c. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.

2. Adjust flow-measuring devices installed in mains and branches to design water flows.

a. Measure flow in main and branch pipes.

b. Adjust main and branch balance valves for design flow.

c. Re-measure each main and branch after all have been adjusted.

3. Adjust flow-measuring devices installed at terminals for each space to design water flows.

a. Measure flow at terminals.

b. Adjust each terminal to design flow.

c. Re-measure each terminal after it is adjusted.

d. Position control valves to bypass the coil and adjust the bypass valve to maintain design flow.

e. Perform temperature tests after flows have been balanced.

4. For systems with pressure-independent valves at terminals:

a. Measure differential pressure and verify that it is within manufacturer's specified range.

b. Perform temperature tests after flows have been verified.

5. For systems without pressure-independent valves or flow-measuring devices at terminals:

    a. Measure and balance coils by either coil pressure drop or temperature method.

    b. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

6. Prior to verifying final system conditions, determine the system pressure-differential set point(s).

7. If the pump discharge valve was used to set total system flow with variable-frequency controller at 60 Hz, at completion, open discharge valve 100 percent, and allow variable-frequency controller to control system differential-pressure set point. Record pump data under both conditions.

8. Mark final settings and verify that all memory stops have been set.

9. Verify final system conditions as follows:

    a. Re-measure and confirm that total flow is within design.

    b. Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.

    c. Mark final settings.

D. For systems with flow diversity:

1. Determine diversity factor.

2. Simulate system diversity by closing required number of control valves, as approved by Architect.

3. Adjust pumps to deliver total design flow.

    a. Measure total water flow.

        1) Position valves for full flow through coils.

        2) Measure flow by main flow meter, if installed.

        3) If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.

    b. Measure pump TDH as follows:

        1) Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.

        2) Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.

        3) Convert pressure to head and correct for differences in gauge heights.

        4) Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.

5) With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.

c. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.

4. Adjust flow-measuring devices installed in mains and branches to design water flows.

   a. Measure flow in main and branch pipes.

   b. Adjust main and branch balance valves for design flow.

   c. Re-measure each main and branch after all have been adjusted.

5. Adjust flow-measuring devices installed at terminals for each space to design water flows.

   a. Measure flow at terminals.

   b. Adjust each terminal to design flow.

   c. Re-measure each terminal after it is adjusted.

   d. Position control valves to bypass the coil and adjust the bypass valve to maintain design flow.

   e. Perform temperature tests after flows have been balanced.

6. For systems with pressure-independent valves at terminals:

   a. Measure differential pressure and verify that it is within manufacturer's specified range.

   b. Perform temperature tests after flows have been verified.

7. For systems without pressure-independent valves or flow-measuring devices at terminals:

   a. Measure and balance coils by either coil pressure drop or temperature method.

   b. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

8. Open control valves that were shut. Close a sufficient number of control valves that were previously open to maintain diversity, and balance terminals that were just opened.

9. Prior to verifying final system conditions, determine system pressure-differential set point(s).

10. If the pump discharge valve was used to set total system flow with variable-frequency controller at 60 Hz, at completion, open discharge valve 100 percent, and allow variable-frequency controller to control system differential-pressure set point. Record pump data under both conditions.

11. Mark final settings and verify that memory stops have been set.

12. Verify final system conditions as follows:

a. Re-measure and confirm that total water flow is within design.

b. Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.

c. Mark final settings.

3.10. PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS

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

B. Adjust pumps to deliver total design flow.

1. Measure total water flow.

a. Position valves for full flow through coils.

b. Measure flow by main flow meter, if installed.

c. If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.

2. Measure pump TDH as follows:

a. Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.

b. Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.

c. Convert pressure to head and correct for differences in gauge heights.

d. Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.

e. With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.

3. Monitor motor performance during procedures, and do not operate motor in an overloaded condition.

C. Adjust flow-measuring devices installed in mains and branches to design water flows.

1. Measure flow in main and branch pipes.

2. Adjust main and branch balance valves for design flow.

3. Re-measure each main and branch after all have been adjusted.

D. Adjust flow-measuring devices installed at terminals for each space to design water flows.

1. Measure flow at terminals.

2. Adjust each terminal to design flow.

3. Re-measure each terminal after it is adjusted.

4. Position control valves to bypass the coil and adjust the bypass valve to maintain design flow.

5. Perform temperature tests after flows have been balanced.

E. For systems with pressure-independent valves at terminals:

1. Measure differential pressure and verify that it is within manufacturer's specified range.

2. Perform temperature tests after flows have been verified.

F. For systems without pressure-independent valves or flow-measuring devices at terminals:

1. Measure and balance coils by either coil pressure drop or temperature method.

2. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

G. Verify final system conditions as follows:

1. Re-measure and confirm that total water flow is within design.

2. Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.

3. Mark final settings.

H. Verify that memory stops have been set.

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 AIR-COOLED CHILLERS

A. Air-Cooled Chillers: Balance water flow through each evaporator to within specified tolerances of indicated flow, with all pumps operating. With only one chiller operating in a multiple-chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:

1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
2. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
3. Power factor if factory-installed instrumentation is furnished for measuring kilowatts.
4. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.
5. Capacity: Calculate in tons of cooling.
6. Efficiency: Calculate operating efficiency for comparison to submitted equipment.
7. Verify condenser-fan rotation and record fan and motor data, including number of fans and entering- and leaving-air temperatures.

3.13. PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering- and leaving-air temperatures.

C. Measure and record entering and leaving refrigerant pressures.

D. Measure and record operating data of compressor(s), fan(s), and motors.

3.14. PROCEDURES FOR HYDRONIC BOILERS

A. Measure and record entering- and leaving-water temperatures.

B. Measure and record water flow.

C. Measure and record pressure drop.

D. Measure and record relief valve(s) pressure setting.

E. Capacity: Calculate in Btu/h (kW) of heating output.

F. Fuel Consumption: If boiler fuel supply is equipped with flow meter, measure and record consumption.

G. Efficiency: Calculate operating efficiency for comparison to submitted equipment.

H. Fan, motor, and motor controller operating data.

3.15. PROCEDURES FOR HYDRONIC 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.

3.16. PROCEDURES FOR ELECTRIC HEATING COILS

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

1. Nameplate data.
2. Airflow.
3. Entering- and leaving-air temperature at full load.
4. Voltage and amperage input of each phase at full load and at each incremental stage.
5. Calculated kilowatt at full load.
6. Fuse or circuit-breaker rating for overload protection.

3.17. PROCEDURES FOR REFRIGERANT COILS

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

1. Dry-bulb temperature of entering and leaving air.
2. Wet-bulb temperature of entering and leaving air.
3. Airflow.
4. Air pressure drop.
5. Refrigerant suction pressure and temperature.

3.18. SOUND TESTS

A. After systems are balanced and Owner Acceptance, measure and record sound levels at up to 10 locations designated by the Engineer.

B. Instrumentation:

1. The sound-testing meter shall be a portable, general-purpose testing meter consisting of a microphone, processing unit, and readout.
2. The sound-testing meter shall be capable of showing fluctuations at minimum and maximum levels and measuring the equivalent continuous sound pressure level (Leq).
3. The sound-testing meter must be capable of using one-third octave band filters to measure mid-frequencies from 31.5 Hz to 8000 Hz.
4. The accuracy of the sound-testing meter shall be plus or minus one decibel.

C. Test Procedures:

1. Perform test at quietest background noise period. Note cause of unpreventable sound that affects test outcome.

2. Equipment should be operating at design values.

3. Calibrate the sound-testing meter prior to taking measurements.

4. Use a microphone suitable for the type of noise levels measured that is compatible with meter. Provide a windshield for outside or in-duct measurements.

5. Record a set of background measurements in dBA and sound pressure levels in the eight unweighted octave bands 63 Hz to 8000 Hz (NC) with the equipment off.

6. Take sound readings in dBA and sound pressure levels in the eight unweighted octave bands 63 Hz to 8000 Hz (NC) with the equipment operating.

7. Take readings no closer than 36 inches from a wall or from the operating equipment and ap-proximately 60 inches from the floor, with the meter held or mounted on a tripod.

8. For outdoor measurements, move sound-testing meter slowly and scan area that has the most exposure to noise source being tested. Use A-weighted scale for this type of reading.

D. Reporting:

1. Report shall record the locations, systems tested, dBA readings and sound pressure levels in each octave band with equipment on and off.

2. Plot sound pressure levels on Noise Criteria (NC) worksheet with equipment on and off.

3.19. VIBRATION TESTS

A. After systems are balanced and substantially complete, measure and record vibration levels on the following equipment:

1. Air handling equipment including air handling units on elevated structure.

2. Fans

3. In-line pumps > 5 hp.

B. Instrumentation:

1. Use portable, battery-operated, and microprocessor-controlled vibration meter with or without a built-in printer.

2. The meter shall automatically identify engineering units, filter bandwidth, amplitude, and frequency scale values.

3. The meter shall be able to measure machine vibration displacement in mils of deflection, velocity in inches per second, and acceleration in inches per second squared.

4. Verify calibration date is current for vibration meter before taking readings.

C. Test Procedures:

1. To ensure accurate readings, verify that accelerometer has a clean, flat surface and is mounted properly.

2. With the unit running, set up vibration meter in a safe, secure location. Connect transducer to meter with proper cables. Hold magnetic tip of transducer on top of the bearing, and measure unit in mils of deflection. Record measurement, then move transducer to the side of the bearing and record in mils of deflection. Record an axial reading in mils of deflection by holding nonmagnetic, pointed transducer tip on end of shaft.

3. Change vibration meter to velocity (inches per second) measurements. Repeat and record above measurements.

4. Record CPM or rpm.

5. Read each bearing on motor, fan, and pump as required. Track and record vibration levels from rotating component through casing to base.

D. Reporting:

1. Report shall record location and the system tested.

2. Include horizontal-vertical-axial measurements for tests.

3. Verify that vibration limits follow Specifications, or, if not specified, follow the General Machinery Vibration Severity Chart or Vibration Acceleration General Severity Chart from AABC's "National Standards for Total System Balance." Acceptable levels of vibration are normally "smooth" to "good."

4. Include in General Machinery Vibration Severity Chart, with conditions plotted.

3.20. DUCT LEAKAGE TESTS

A. Witness the duct leakage testing performed by Installer.

B. Verify that proper test methods are used and that leakage rates are within specified limits.

C. Report deficiencies observed.

3.21. PIPE LEAKAGE TESTS

A. Witness the pipe pressure testing performed by Installer.

B. Verify that proper test methods are used and that leakage rates are within specified limits.

C. Report deficiencies observed.

3.22. 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 10 percent or minus 5 percent.

3. Heating Water Flow Rate: Plus 10 percent or minus 5 percent.

4. Cooling Water Flow Rate: Plus 10 percent or minus 5 percent.

5. Condenser Water Flow Rate: Plus 10 percent or minus 5 percent.

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

3.23. FINAL REPORT

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

1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.

2. Include a list of instruments used for procedures, along with proof of calibration.

3. Certify validity and accuracy of field data.

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

1. Pump curves.

2. Fan curves.

3. Manufacturers' test data.

4. Field test reports prepared by system and equipment installers.

5. Other information relative to equipment performance; do not include Shop Drawings and Product Data.

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

1. Title page.

2. Name and address of the TAB specialist.

3. Project name.

4. Project location.

5. Architect's name and address.

6. Engineer's name and address.

7. Contractor's name and address.

8. Report date.

9. Signature of TAB supervisor who certifies the report.

10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.

11. Summary of contents, including indicated versus final performance; notable characteristics of systems; and description of system operation sequence if it varies from the Contract Documents.

12. Nomenclature sheets for each item of equipment.

13. Data for terminal units, including manufacturer's name, type, size, and fittings.

14. Notes to explain why certain final data in the body of reports vary from indicated values.

15. Test conditions for fans performance forms, including the following:

    a. Settings for outdoor, return, and exhaust-air dampers.

    b. Conditions of filters.

    c. Cooling coil, wet- and dry-bulb conditions.

    d. Heating coil, dry-bulb conditions.

    e. Face and bypass damper settings at coils.

    f. Fan drive settings, including settings and percentage of maximum pitch diameter.

    g. Variable speed controller settings.

    h. Settings for pressure controller(s).

    i. Other system operating conditions that affect performance.

16. Test conditions for pump performance forms, including the following:

    a. Variable-frequency controller settings for variable-flow hydronic systems.

    b. Settings for pressure controller(s).

    c. Other system operating conditions that affect performance.

D. Floor Plans: Include a copy of the ductwork plans, from either the Mechanical Contract Documents or Mechanical Contractor’s sheet metal fabrication documents, with final air flow values of all airside equipment and of each air inlet and outlet superimposed.

   1. The floor plans are in addition to the written report. The values on the plans should match those in the written report and provide an easy reference to the location of each device.

E. 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.

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

1. Unit Data:
   a. Unit identification.
   b. Location.
   c. Make and type.
   d. Model number and unit size.
   e. Manufacturer's serial number.
   f. Unit arrangement and class.
   g. Discharge arrangement.
   h. Sheave make, size in inches, and bore.
   i. Center-to-center dimensions of sheave and amount of adjustments in inches.
   j. Number, make, and size of belts.
   k. Number, type, and size of filters.
2. Motor Data:
   a. Motor make, and frame type and size.
   b. Horsepower and speed.
   c. Volts, phase, and hertz.
   d. Full-load amperage and service factor.
   e. Sheave make, size in inches, and bore.
   f. Center-to-center dimensions of sheave and amount of adjustments in inches.
3. Test Data (Indicated and Actual Values):
   a. Total airflow rate in cfm.
   b. Total system static pressure in inches wg.
   c. Fan speed.
   d. Inlet and discharge static pressure in inches wg.
   e. Profile of internal pressure losses across each internal component, for example: fan, cooling coil, heating coil, filters, dampers, etc.
      1) Exception: Profiles are not required for air handling equipment with capacities of 5,000 cfm and smaller.
   f. For each filter bank, filter static-pressure differential in inches wg.
   g. Preheat-coil static-pressure differential in inches wg.

h. Cooling-coil static-pressure differential in inches wg.

i. Heating-coil static-pressure differential in inches wg.

j. List for each internal component with pressure-drop, static-pressure differential in inches wg.

k. Outdoor airflow in cfm.

l. Return airflow in cfm.

m. Outdoor-air damper position.

n. Return-air damper position.

G. Apparatus-Coil Test Reports:

1. Coil Data:

a. System identification.

b. Location.

c. Coil type.

d. Number of rows.

e. Fin spacing in fins per inch o.c.

f. Make and model number.

g. Face area in sq. ft.

h. Tube size in NPS.

i. Tube and fin materials.

j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.

b. Average face velocity in fpm.

c. Air pressure drop in inches wg.

d. Outdoor-air, wet- and dry-bulb temperatures in deg F.

e. Return-air, wet- and dry-bulb temperatures in deg F.

f. Entering-air, wet- and dry-bulb temperatures in deg F.

g. Leaving-air, wet- and dry-bulb temperatures in deg F.

h. Water flow rate in gpm.

i. Water pressure differential in feet of head or psig.

j. Entering-water temperature in deg F.

k. Leaving-water temperature in deg F.

l. Refrigerant expansion valve and refrigerant types.

m. Refrigerant suction pressure in psig.

n. Refrigerant suction temperature in deg F.

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

1. Unit Data:

    a. System identification.

    b. Location.

    c. Make and type.

    d. Model number and unit size.

    e. Manufacturer's serial number.

    f. Fuel type in input data.

    g. Output capacity in Btu/h (kW).

    h. Ignition type.

    i. Burner-control types.

    j. Motor horsepower and speed.

    k. Motor volts, phase, and hertz.

    l. Motor full-load amperage and service factor.

    m. Sheave make, size in inches, and bore.

    n. Center-to-center dimensions of sheave and amount of adjustments in inches.

2. Test Data (Indicated and Actual Values):

    a. Total airflow rate in cfm.

    b. Entering-air temperature in deg F.

    c. Leaving-air temperature in deg F.

    d. Air temperature differential in deg F.

    e. Entering-air static pressure in inches wg.

    f. Leaving-air static pressure in inches wg.

    g. Air static-pressure differential in inches wg.

h. Low-fire fuel input in Btu/h.

i. High-fire fuel input in Btu/h.

j. Manifold pressure in psig.

k. High-temperature-limit setting in deg F.

l. Operating set point in Btu/h.

m. Motor voltage at each connection.

n. Motor amperage for each phase.

o. Heating value of fuel in Btu/h.

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

1. Unit Data:

a. System identification.

b. Location.

c. Coil identification.

d. Capacity in Btu/h.

e. Number of stages.

f. Connected volts, phase, and hertz.

g. Rated amperage.

h. Airflow rate in cfm.

i. Face area in sq. ft.

j. Minimum face velocity in fpm.

2. Test Data (Indicated and Actual Values):

a. Heat output in Btu/h.

b. Airflow rate in cfm.

c. Air velocity in fpm.

d. Entering-air temperature in deg F.

e. Leaving-air temperature in deg F.

f. Voltage at each connection.

g. Amperage for each phase.

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

1. Fan Data:
    a. System identification.
    b. Location.
    c. Make and type.
    d. Model number and size.
    e. Manufacturer's serial number.
    f. Arrangement and class.
    g. Sheave make, size in inches, and bore.
    h. Center-to-center dimensions of sheave and amount of adjustments in inches.
2. Motor Data:
    a. Motor make, and frame type and size.
    b. Horsepower and speed.
    c. Volts, phase, and hertz.
    d. Full-load amperage and service factor.
    e. Sheave make, size in inches, and bore.
    f. Center-to-center dimensions of sheave and amount of adjustments in inches.
    g. Number, make, and size of belts.
3. Test Data (Indicated and Actual Values):
    a. Total airflow rate in cfm.
    b. Total system static pressure in inches wg.
    c. Fan speed.
    d. Discharge static pressure in inches wg.
    e. Suction static pressure in inches wg.

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

1. Report Data:
    a. System fan and air-handling-unit number.
    b. Location and zone.
    c. Traverse air temperature in deg F.
    d. Duct static pressure in inches wg.

e. Duct size in inches.

f. Duct area in sq. ft.

g. Indicated airflow rate in cfm.

h. Indicated velocity in fpm.

i. Actual airflow rate in cfm.

j. Actual average velocity in fpm.

k. Barometric pressure in psig.

L. Air-Terminal-Device Reports:

1. Unit Data:

a. System and air-handling unit identification.

b. Location and zone.

c. Apparatus used for test.

d. Area served.

e. Make.

f. Number from system diagram.

g. Type and model number.

h. Size.

i. Effective area in sq. ft.

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.

b. Air velocity in fpm.

c. Preliminary airflow rate as needed in cfm.

d. Preliminary velocity as needed in fpm.

e. Final airflow rate in cfm.

f. Final velocity in fpm.

g. Space temperature in deg F.

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

1. Unit Data:

a. System and air-handling-unit identification.

b. Location and zone.

c. Room or riser served.

d. Coil make and size.

e. Flowmeter type.

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.

b. Entering-water temperature in deg F.

c. Leaving-water temperature in deg F.

d. Water pressure drop in feet of head or psig.

e. Entering-air temperature in deg F.

f. Leaving-air temperature in deg F.

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

1. Unit Data:

a. Unit identification.

b. Location.

c. Service.

d. Make and size.

e. Model number and serial number.

f. Water flow rate in gpm.

g. Water pressure differential in feet of head or psig.

h. Required net positive suction head in feet of head or psig.

i. Pump speed.

j. Impeller diameter in inches.

k. Motor make and frame size.

l. Motor horsepower and rpm.

m. Voltage at each connection.

n. Amperage for each phase.

o. Full-load amperage and service factor.

p. Seal type.

2. Test Data (Indicated and Actual Values):

a. Static head in feet of head or psig.

b. Pump shutoff pressure in feet of head or psig.

c. Actual impeller size in inches.

d. Full-open flow rate in gpm.

e. Full-open pressure in feet of head or psig.

f. Final discharge pressure in feet of head or psig.

g. Final suction pressure in feet of head or psig.

h. Final total pressure in feet of head or psig.

i. Final water flow rate in gpm.

j. Voltage at each connection.

k. Amperage for each phase.

3.24. INSPECTIONS

A. Initial Inspection:

1. After testing and balancing is 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. Perform the inspection in the presence of the owner’s commissioning agent.

3. Check the following for each system:

a. Measure airflow of at least 10 percent of air outlets.

b. Measure water flow of at least 10 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. The TAB contractor's test and balance engineer shall conduct the inspection in the presence of the engineer.

2. 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.

3. 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."

4. 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.

3.25. 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

SECTION 23 07 13 – DUCT AND DUCTED EQUIPMENT INSULATION

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes insulation of indoor and outdoor supply, return, exhaust, relief and ventilation duct systems.

1.2. SUBMITTALS

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

1.3. QUALITY ASSURANCE

A. 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. Indoors: Flame-spread index of 25 or less and smoke-developed index of 50 or less.

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

1.4. 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.

B. Storage: Insulation material shall be stored in a dry location sealed in plastic to prevent moisture infiltration. Insulation material, installed or not, that becomes wet, dirty, etc. shall be removed and replaced. “Dried” or “cleaned” insulation materials shall not be used.

1.5. COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields.

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.

1.6. SCHEDULING

A. Schedule insulation installation after pressure testing duct systems. Application may begin on segments that have satisfactory test results. Insulation applied prior to satisfactory test results shall be removed and replaced.

PART 2 - PRODUCTS

2.1. INSULATION MATERIALS

A. General: Comply with requirements in Indoor Duct Insulation and Field-Applied Jacket Schedule and Outdoor Duct Insulation and Field-Applied Jacket Schedule articles for where insulating materials shall be applied.

1. Products shall not contain asbestos, lead, mercury, or mercury compounds.
2. 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.
3. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
4. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

B. Mineral-Fiber Blanket Insulation: Mineral wool or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290. Provide Type II with factory-applied vinyl jacket; Type III with factory-applied FSK jacket; or Type III with factory-applied FSP jacket.

1. R-value requirements defined in Part 3 of this section as based on installed ratings with 25 percent compression.

C. Mineral-Fiber Board Insulation: Mineral wool 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 jacket.

D. Polyisocyanurate Board Insulation: Closed-cell polyisocyanurate rigid foam boards with aluminum foil facing, ASTM C 1289, Type 1, Grade 1 (-100 to +250F). For outdoor use only.

E. Fire-Rated Blanket: High-temperature, flexible, blanket insulation with FSK jacket that is tested and certified to provide a 2-hour fire rating by an NRTL acceptable to authorities having jurisdiction.

2.2. FACTORY-APPLIED JACKETS

A. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White outward facing, bleached kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing.
2. FSK Jacket: Aluminum-foil outward facing, fiberglass-reinforced scrim with brown kraft-paper backing.
3. PSK Jacket: White outward facing, bleached kraft paper laminated with polypropylene film, fiberglass-reinforced scrim.

2.3. FIELD-APPLIED JACKETS

A. Insulation system schedules indicate field-applied jackets for various applications. When field-applied jackets are indicated, comply with the following:

1. Aluminum Jacket: Comply with ASTM B 209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.

    a. Moisture Barrier:

        1) Indoor Applications: 3-mil thick, heat-bonded polyethylene and kraft paper.

2. Stainless-Steel Jacket: ASTM A 167 or ASTM A 240/A 240M.

    a. Moisture Barrier:

        1) Indoor Applications: 3-mil thick, heat-bonded polyethylene and kraft paper.

3. PVC Jacket: High-impact resistant, UV-resistant PVC complying with ASTM D1784, Class 16354-C, 20-mils thick.

    a. Adhesive: As recommended by jacket material manufacturer.

    b. Color: Comply with Section 230553.

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

2.4. DUCT INSULATION INSTALLATION MATERIALS

A. General: Adhesives, mastics and sealants shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated. Indoor applications shall comply with low-VOC requirements of Section 230100.

B. Adhesives:

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

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

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

C. Mastics: Comply with MIL-PRF-19565C, Type II.

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

D. Sealants:

1. ASJ Flashing Sealants and Vinyl Flashing Sealants.

2. FSK and Metal Jacket Flashing Sealants.

E. Tapes:

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

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

3. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

F. Securements:

1. Insulation Pins and Hangers:

a. Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.135-inch diameter shank, length to suit depth of insulation indicated.

b. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding 0.135-inch diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.

c. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

d. Non-Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

e. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

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

g. Non-Metal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

2. Staples: Outward-clinching insulation staples, nominal 3/4-inch- wide, stainless steel or Monel.

3. Wire: 0.062-inch soft-annealed, stainless steel.

G. Corner Angles:

1. Aluminum Corner Angles: 0.040-inch thick, minimum 1 by 1-inch, aluminum according to ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14.

2. Stainless-Steel Corner Angles: 0.024-inch thick, minimum 1 by 1-inch, stainless steel according to ASTM A 167 or ASTM A 240/A 240M, Type 304.

PART 3 - EXECUTION

3.1. INDOOR DUCT INSULATION AND FIELD-APPLIED JACKET SCHEDULE

A. General

1. Unconditioned spaces include attics, crawl spaces, and unheated mechanical rooms. They do not include vertical shafts surrounded by conditioned spaces.

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

B. General Duct Systems

1. Concealed single-wall duct in conditioned spaces:

   a. Supply and Ventilation Air: 2-inches (R-6) of mineral fiber blanket, field-applied jacket is not required.

   b. Return and Relief Air: 2-inches (R-6) of mineral fiber blanket, field-applied jacket is not required.

   c. General Building Exhaust Air: None.

2. Concealed single-wall duct in unconditioned spaces:

   a. Supply and Ventilation Air: 2-inches (R-6) of mineral fiber blanket, field-applied jacket is not required.

   b. Return and Relief Air: 2-inches (R-6) of mineral fiber blanket, field-applied jacket is not required.

   c. General Building Exhaust Air: None.

3. Exposed-to-view single-wall duct in mechanical equipment spaces:

   a. Supply and Ventilation Air: 2-inches (R-6) of mineral fiber board for rectangular duct and mineral fiber blanket for round and flat oval with 0.032-inch thick stucco embossed aluminum field-applied jacket.

   b. Return and Relief Air: 2-inches (R-6) of mineral fiber board for rectangular duct and mineral fiber blanket for round and flat oval with 0.032-inch thick stucco embossed aluminum field-applied jacket.

   c. General Building Exhaust Air: None.

4. Exposed-to-view single-wall duct in unconditioned spaces:

   a. Supply and Ventilation Air: 2-inches (R-6) of mineral fiber blanket with 0.032-inch thick painted smooth aluminum field-applied jacket.

   b. Return and Relief Air: 2-inches (R-6) of mineral fiber blanket with 0.032-inch thick painted smooth aluminum field-applied jacket.

   c. General Building Exhaust Air: None.

5. Concealed or exposed-to-view double-wall duct interstitial insulation in conditioned spaces:

a. Supply and Ventilation Air: 2-inches (R-6) of mineral fiber blanket, field-applied jacket is not required.

b. Return and Relief Air: 2-inches (R-6) of mineral fiber blanket, field-applied jacket is not required.

6. Concealed or exposed-to-view double-wall duct interstitial insulation in unconditioned spaces:

a. Supply and Ventilation Air: 2-inches (R-6) of mineral fiber blanket, field-applied jacket is not required.

b. Return and Relief Air: 2-inches (R-6) of mineral fiber blanket, field-applied jacket is not required.

7. Concealed within chase on an exterior wall or within an exterior wall:

a. Supply and Ventilation Air: 2-inches (R-8) of mineral fiber board, field-applied jacket is not required.

b. Return and Relief Air: 2-inches (R-8) of mineral fiber board, field-applied jacket is not required.

C. Air Plenums

1. Plenums connected to outdoor louvers or hoods:

a. Ventilation Air: 3-inches (R-8) of mineral fiber board with 0.032-inch thick stucco embossed aluminum.

b. Exhaust/Relief Air: 2-inches (R-6) of mineral fiber board with 0.032-inch thick stucco embossed aluminum.

2. Plenums not connected directly to the outdoors:

a. Supply Air: 2-inches (R-6) of mineral fiber board with 0.032-inch thick stucco embossed aluminum.

b. Ventilation Air: 3-inches (R-8) of mineral fiber board with 0.032-inch thick stucco embossed aluminum.

c. Exhaust/Relief Air: 2-inches (R-6) of mineral fiber board with 0.032-inch thick stucco embossed aluminum.

3.2. OUTDOOR DUCT INSULATION AND FIELD-APPLIED JACKET SCHEDULE

A. General Duct Systems

1. Double-wall duct interstitial insulation:

a. Supply, Ventilation and Return Air: 2-inches (R-10) of polyisocyanurate, field-applied jacket is not required.

b. Exhaust/Relief Air: None.

B. Plenums

1. Plenums shall be insulated as follows:

    a. Supply, Ventilation and Return Air: 2-inches (R-10) of polyisocyanurate with 0.032-inch thick stucco embossed aluminum.

    b. Exhaust/Relief Air: None.

3.3. GENERAL REQUIREMENTS

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.

3.4. PREPARATION

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

3.5. GENERAL INSTALLATION REQUIREMENTS

A. Insulate all components of duct systems as specified with the exception of the following components:

1. Fibrous-glass ducts.

2. Factory-insulated flexible ducts.

3. Factory-insulated plenums and casings.

4. Flexible connectors.

5. Vibration-control devices.

6. Factory-insulated access panels and doors.

B. Provide rigid board insulation strips at duct supports to avoid compression of duct wrap.

C. For ductwork conveying air below ambient temperature, insulate entire system including fittings, joints, flanges, fire dampers, flexible connections, expansion joints, and the backs of supply diffusers.

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

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

F. 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.

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

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

I. Keep insulation materials dry during application and finishing.

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

K. Install insulation with least number of joints practical.

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

1. Install insulation continuously through hangers and around anchor attachments.

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

3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

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

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

1. Draw jacket tight and smooth.

2. Cover circumferential joints with 3-inch wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.

3. Overlap jacket longitudinal seams at least 1-1/2 inches. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches o.c.

4. For below ambient services, apply vapor-barrier mastic over staples.

5. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.

6. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.

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

P. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

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

3.6. PENETRATIONS

A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.

1. Seal penetrations with flashing sealant.

2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.

3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.

4. Seal jacket to roof flashing with flashing sealant.

B. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.

1. Seal penetrations with flashing sealant.

2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.

3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.

4. Seal jacket to wall flashing with flashing sealant.

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

D. Insulation Installation at Fire-Rated Wall and Partition Penetrations: 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.

E. Insulation Installation at Floor Penetrations:

1. Duct: For penetrations through fire-rated assemblies, terminate insulation at fire damper sleeves and externally insulate damper sleeve beyond floor to match adjacent duct insulation. Overlap damper sleeve and duct insulation at least 2 inches.

2. Seal penetrations through fire-rated assemblies.

3.7. 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.

2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.

3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

    a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.

    b. On duct sides with dimensions larger than 18 inches, place pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.

    c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.

    d. Do not over-compress insulation during installation.

    e. Impale insulation over pins and attach speed washers.

    f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

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

    a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.

    b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops 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.

5. Overlap un-faced blankets a minimum of 2 inches on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches o.c.

6. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.

7. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

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.

2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.

3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

   a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.

   b. On duct sides with dimensions larger than 18 inches, space pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.

   c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.

   d. Do not over-compress insulation during installation.

   e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

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

   a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.

   b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops 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.

5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.

6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

3.8. INSTALLATION OF POLYISOCYANURATE INSULATION

A. 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.

2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.

3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

   a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.

   b. On duct sides with dimensions larger than 18 inches, space pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.

   c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.

   d. Do not over-compress insulation during installation.

   e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

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

   a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.

   b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops 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.

5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.

6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

3.9. FIELD-APPLIED JACKET INSTALLATION

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

   1. Draw jacket smooth and tight to surface with 2-inch overlap at seams and joints.

2. Embed glass cloth between two 0.062-inch thick coats of lagging adhesive.

3. Completely encapsulate insulation with coating, leaving no exposed insulation.

B. Where FSK jackets are indicated, install as follows:

1. Draw jacket material smooth and tight.

2. Install lap or joint strips with same material as jacket.

3. Secure jacket to insulation with manufacturer's recommended adhesive.

4. Install jacket with 1-1/2-inch laps at longitudinal seams and 3-inch wide joint strips at end joints.

5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

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

3.10. FIRE-RATED INSULATION SYSTEM INSTALLATION

A. Where fire-rated insulation system is indicated, secure system to ducts and duct hangers and supports to maintain a continuous fire rating.

B. Insulate duct access panels and doors to achieve same fire rating as duct.

C. Install firestopping at penetrations through fire-rated assemblies. Fire-stop systems are specified in Section 230500.

3.11. FINISHES

A. Paint duct insulation with ASJ, glass-cloth, or other paintable jacket material. Color shall be selected by the Owner/Engineer. Refer to Section 230553.

1. Prime with 2 coats of water-based white acrylic primer paint designed for use with associated jacket material.

2. Finish with 2 coats of flat latex paint with fungicidal agent additive to render fabric mildew proof.

3. Do not field paint stainless-steel jackets.

B. Apply paint and primer at the recommended spreading rate and film thickness as recommended by the paint manufacturer.

C. Apply paint and primer within the environmental conditions recommended by the paint manufacturer but not less than 55 deg F; not more than 90 deg F; and not more than 70 percent RH.

END OF SECTION

SECTION 23 07 19 – PIPING AND PIPED EQUIPMENT INSULATION

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes insulation of HVAC piping systems:

1.2. SUBMITTALS

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

1.3. QUALITY ASSURANCE

A. 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. Indoors installed in air plenums: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.

2. Indoors not installed in air plenums: Flame-spread index of 25 or less, and smoke-developed index of 450 or less.

3. Outdoors: Flame-spread index of 25 or less, and smoke-developed index of 450 or less.

1.4. 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.

B. Storage: Insulation material shall be stored in a dry location sealed in plastic to prevent moisture infiltration. Insulation material, installed or not, that becomes wet, dirty, etc. shall be removed and replaced. “Dried” or “cleaned” insulation materials shall not be used.

1.5. COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields.

B. Coordinate clearance requirements with piping installer for piping insulation application. Before preparing piping shop drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

C. Coordinate installation and testing of heat tracing.

1.6. SCHEDULING

A. Schedule insulation installation after pressure testing systems and where required after installing and testing heat tracing. Insulation applied prior to satisfactory test results shall be removed and replaced.

PART 2 - PRODUCTS

2.1. INSULATION MATERIALS

A. General: Comply with requirements in Piping Insulation Schedule and Field-Applied Jacket Schedule articles for where insulating materials shall be applied.

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

2. 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.

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

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

5. Fitting Covers: Field apply insulation to cover valves, elbows, tees, and flanges.

B. Mineral-Fiber, Preformed Pipe Insulation:

1. Type I, 850 deg F Materials: Mineral wool or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ-SSL. Johns Manville Micro-Lok, Owens Corning Fiberglas or Engineer approved equal.

2. Type II, 1200 deg F Materials: Mineral wool or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type II, Grade A, with factory-applied ASJ-SSL. Owens Corning Thermafiber or Engineer approved equal.

3. Thermal conductivity (k-value) maximum value of 0.34 BTU in /(hr sqft deg F) for fluid temperatures above 350 deg F; 0.32 for fluids 350 deg F and lower; 0.30 for fluids 250 deg F and lower; 0.29 for fluids 200 deg F and lower; 0.27 for fluids 60 deg F and lower; and 0.26 for fluids 40 deg F and lower.

C. Mineral-Fiber, Pipe and Tank Insulation: Mineral wool or glass fibers bonded with a thermosetting resin. Semi-rigid board material with factory-applied ASJ jacket complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density shall be 2.5 lb/cu. ft. or more. Owens Corning Fiberglas Pipe and Tank or Engineer approved equal.

1. Thermal conductivity (k-value) maximum value of 0.34 BTU in /(hr sqft deg F) for fluid temperatures above 350 deg F; 0.32 for fluids 350 deg F and lower; 0.30 for fluids 250 deg F and lower; 0.29 for fluids 200 deg F and lower; 0.27 for fluids 60 deg F and lower; and 0.26 for fluids 40 deg F and lower.

D. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials. Armacell AP Armaflex or Engineer approved equal.

1. Thermal conductivity (k-value) maximum value of 0.15 BTU in /(hr sqft deg F) for fluid temperatures 60 deg F and lower

E. Polyisocyanurate: Unfaced, preformed, rigid cellular polyisocyanurate material intended for use as thermal insulation with factory-applied ASJ-SSL. Johns Manville Trymer or Engineer approved equal.

1. Thermal conductivity (k-value) maximum value of 0.19 BTU in /(hr sqft deg F) for fluid temperatures 60 deg F and lower and 0.23 for fluids 40 deg F and lower.

2. Provide Type V for insulation in exposed locations below 6 feet above finished floor, exterior locations, and other locations subject to damage. Provide Type IV for insulation in exposed locations above 6 feet above finished floor and concealed locations.

3. Fabricate shapes according to ASTM C 450 and ASTM C 585.

F. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells with factory-applied ASJ-SSL. Comply with ASTM C 552, ASTM C 450 and ASTM C 585. Owens Corning Foamglas or Engineer approved equal.

1. Thermal conductivity (k-value) maximum value of 0.30 BTU in /(hr sqft deg F) for fluid temperatures 60 deg F and lower and 0.29 for fluids 40 deg F and lower.

G. Phenolic: Unfaced, preformed, rigid cellular high density phenolic material intended for use as thermal insulation. Comply with ASTM C 518. Johns Manville Trymer Supercel or Engineer approved equal.

1. Thermal conductivity (k-value) maximum value of 0.23 BTU in /(hr sqft deg F) for fluid temperatures 60 deg F and lower.

2. Fabricate shapes according to ASTM C 450 and ASTM C 585.

3. Vapor retarder shall be 4 mil 0.02 perm ASTM E96 vapor retarder film with protective jacketing and vapor retarder tape.

H. Calcium Silicate: Inorganic, non-combustible, hydrous calcium silicate with non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I with a maximum use temperature of 1200 deg F. Provide preformed sections for piping. Johns Manville Thermo-1200 or Engineer approved equal.

1. Thermal conductivity (k-value) maximum value of 0.43 BTU in /(hr sqft deg F) for fluid temperatures over 350 deg F, 0.41 for fluids 350 deg F and lower, and 0.39 for fluids 250 deg F and lower.

2. Prefabricated Fitting Covers: Comply with ASTM C 450 and ASTM C 585 for dimensions used in preforming insulation to cover valves, elbows, tees, and flanges.

2.2. FACTORY-APPLIED JACKETS

A. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White outward facing, bleached kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing.

2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.

3. FSK Jacket: Aluminum-foil outward facing, fiberglass-reinforced scrim with brown kraft-paper backing.

4. PSK Jacket: White outward facing, bleached kraft paper laminated with polypropylene film, fiberglass-reinforced scrim.

2.3. FIELD-APPLIED JACKETS

A. Insulation system schedules indicate field-applied jackets for various applications. When field-applied jackets are indicated, comply with the following:

1. Aluminum Jacket: Comply with ASTM B 209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.

   a. Moisture Barrier:

      1) Indoor Applications: 1.5-mil thick, heat-bonded polyethylene and kraft paper.

      2) Outdoor Applications: 3.0-mil thick polysurlyn.

2. Stainless-Steel Jacket: ASTM A 167 or ASTM A 240/A 240M.

   a. Moisture Barrier:

      1) Indoor Applications: 1.5-mil thick, heat-bonded polyethylene and kraft paper.

      2) Outdoor Applications: 3.0-mil thick polysurlyn.

3. PVC Jacket: High-impact resistant, UV-resistant PVC complying with ASTM D1784, Class 16354-C, 20-mils thick.

   a. Adhesive: As recommended by jacket material manufacturer.

   b. Color: Select from manufacturer’s available pre-colored options. Do not paint in the field. Color scheme shall comply with Section 230553.

   c. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.

      1) Shapes: 45- and 90-degree, short- and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.

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

2.4. INSULATING CEMENTS

A. Mineral-Fiber Insulating Cement: Comply with ASTM C 195.

B. Expanded or Exfoliated Vermiculite Insulating Cement: Comply with ASTM C 196.

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

2.5. PIPING INSULATION INSTALLATION MATERIALS

A. General: Adhesives, mastics and sealants shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated. Indoor applications shall comply with low-VOC requirements of Section 230100.

B. Adhesives:

1. Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.
2. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
3. ASJ Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.
4. FSK Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.
5. PVC Jacket Adhesive: Compatible with PVC jacket.
6. Polyisocyanurate Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 deg F.
7. 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.
8. Phenolic Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 deg F.
9. Calcium Silicate Adhesive: Fibrous, sodium-silicate-based adhesive with a service temperature range of 50 to 800 deg F.

C. Mastics: Comply with MIL-PRF-19565C, Type II.

1. Vapor-Barrier Mastic: Water based, white, suitable for indoor use on below-ambient services with water-vapor permeance of 0.013 perm at 43-mil dry film thickness per ASTM E 96/E 96M, Procedure B; service temperature range of minus 20 to plus 180 deg F; and solids content of 58 percent by volume and 70 percent by weight per ASTM D 1644.
2. Breather Mastic: Water based; white, suitable for indoor and outdoor use on above-ambient services with service temperature range of minus 20 to plus 180 deg F; water-vapor permeance of 1.8 perms at 0.0625-inch dry film thickness per ASTM F 1249; and solids content of 60 percent by volume and 66 percent by weight.

D. Sealants:

1. Joint Sealants: Permanently flexible, white or gray, elastomeric sealant with service temperature range of minus100 to plus 300 deg F.

2. FSK and Metal Jacket Flashing Sealants: Fire and water-resistant, aluminum color, flexible, elastomeric sealant with service temperature range of minus 40 to plus 250 deg F.

3. ASJ Flashing Sealants and Vinyl and PVC Jacket Flashing Sealants: Fire and water-resistant, white, flexible, elastomeric sealant with service temperature range of minus 40 to plus 250 deg F.

E. Tapes:

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

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

3. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

4. PVC Tape: Vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.

5. PVDC Tape: Vapor-retarder tape matching field-applied vapor retarder film with acrylic adhesive; suitable for indoor and outdoor applications.

F. Securements:

1. Bands:

a. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 304 or Type 316; 0.015-inch thick, 3/4-inch wide with wing seal.

b. Aluminum: ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020-inch thick, 3/4-inch wide with wing seal.

2. Staples: Outward-clinching insulation staples, nominal 3/4-inch wide, stainless steel or Monel.

3. Wire: 0.062-inch soft-annealed, stainless steel.

4. Insulation Pins and Hangers:

a. Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.135-inch diameter shank, length to suit depth of insulation indicated.

b. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding 0.135-inch diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.

c. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

d. Non-Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

e. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

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

g. Non-Metal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

5. Corner Angles:

a. Aluminum Corner Angles: 0.040-inch thick, minimum 1 by 1-inch, aluminum according to ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14.

b. Stainless-Steel Corner Angles: 0.024-inch thick, minimum 1 by 1-inch, stainless steel according to ASTM A 167 or ASTM A 240/A 240M, Type 304.

PART 3 - EXECUTION

3.1. PIPING INSULATION SCHEDULE

A. General:

1. Unconditioned spaces include attics, crawl spaces, and unheated mechanical rooms. They do not include vertical shafts surrounded by conditioned spaces.

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

3. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:

a. Drainage piping located in crawl spaces.

b. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

B. Condensate and Equipment Drain Water, 60 deg F and lower:

1. Indoor Piping:

a. Cellular Glass: 1 1/2-inches thick for 3/4 to 6-inches NPS.

b. Polyisocyanurate: 1-inch thick for 3/4 to 6-inches NPS.

c. Elastomeric: 1-inch thick for 3/4 to 2-inches NPS.

2. Outdoor Piping, Above-Grade:

    a. Cellular Glass: 1 1/2-inches thick for 3/4 to 6-inches NPS.

    b. Polyisocyanurate: 1-inch thick for 3/4 to 6-inches NPS.

    c. Elastomeric: 1-inch thick for 3/4 to 2-inches NPS.

C. Chilled Water above 40 deg F:

1. Indoor Piping:

    a. Cellular Glass: 2-inches thick for 3/4 to 10-inches NPS; and 3-inches thick for 12 to 24-inches NPS.

    b. Polyisocyanurate: 1 1/2-inches thick for 3/4 to 24-inches NPS.

    c. Elastomeric: 1 1/2-inches thick for 3/4 to 2-inches NPS.

2. Outdoor Piping, Above-Grade:

    a. Cellular Glass: 3-inches thick for up to 24-inches NPS.

    b. Polyisocyanurate: 2-inches thick for up to 24-inches NPS.

    c. Phenolic: 2-inches thick for up to 24-inches NPS.

    d. Elastomeric: 2-inches thick for 3/4 to 2-inches NPS.

D. Heating-Hot-Water Supply and Return, 200 deg F and below:

1. Indoor Piping:

    a. Mineral-Fiber: 1-1/2-inches thick for 3/4 to 1-1/4-inches NPS; 2-inches thick for 1 1/2 to 10-inches NPS; and 3-inches thick for 12 to 24-inches NPS.

2. Outdoor Piping, Above-Grade:

    a. Mineral-Fiber: 2-inches thick for 3/4 to 1-1/4-inches NPS; and 3-inches thick for 1 1/2 to 24-inches NPS.

E. Refrigerant Suction and Hot-Gas Piping:

1. Indoor Piping:

    a. Mineral-Fiber: 1-1/2-inches thick for 3/4 to 1-1/2-inches NPS; 2-inches thick for 2-inches NPS and larger.

    b. Elastomeric: 1 1/2-inches thick for 3/4 to 1-1/2-inches NPS.

2. Outdoor Piping, Above-Grade:

    a. Elastomeric: 1 1/2-inches thick for 3/4 to 1-inch NPS.

3.2. EQUIPMENT INSULATION SCHEDULE

A. Insulate indoor and outdoor equipment that is not factory insulated.

B. Chillers: Insulate cold surfaces on chillers, including, but not limited to, evaporator bundles, condenser bundles, heat-recovery bundles, suction piping, compressor inlets, tube sheets, water boxes, and nozzles with one of the following:

1. Cellular Glass: 2-inches thick.
2. Flexible Elastomeric: 1 1/2-inches thick.
3. Polyisocyanurate: 1 1/2-inches thick.

C. Cooling Equipment: Insulate cooling equipment such as heat exchangers, air separators, expansion/compression tanks, buffer tanks, etc. with one of the following:

1. Cellular Glass: 2-inches thick.
2. Flexible Elastomeric: 1 1/2-inches thick.
3. Polyisocyanurate: 1 1/2-inches thick.

D. Chilled and Cold Water Pumps: Insulate pumps with one of the following:

1. Cellular Glass: 2-inches thick.
2. Flexible Elastomeric: 1 1/2-inches thick.
3. Polyisocyanurate: 1 1/2-inches thick.

E. Heating Equipment: Insulate heating equipment such as heat exchangers, air separators, expansion/compression tanks, etc. with one of the following:

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

F. Heating and Hot Water Pumps: Insulate pumps with one of the following:

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

3.3. 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. Indoor Equipment and Piping Jacket:

1. Concealed Piping: None.
2. Exposed Piping: 20 mils thick PVC.

C. Outdoor Equipment and Piping Jacket:

1. Above Ground Piping: 0.032-inch thick stucco embossed aluminum.
2. Equipment: 0.032-inch thick stucco embossed aluminum.

3.4. 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.

3.5. PREPARATION

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

B. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.

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

3.6. 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. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.

G. Keep insulation materials dry during application and finishing.

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

I. Install insulation with least number of joints practical.

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

1. Install insulation continuously through hangers and around anchor attachments.

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

3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.

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

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

1. Draw jacket tight and smooth.

2. Cover circumferential joints with 3-inch wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.

3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches o.c.

a. For below-ambient services, apply vapor-barrier mastic over staples.

4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.

5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.

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

N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

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

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

1. Vibration-control devices.

2. Testing agency labels and stamps.

3. Nameplates and data plates.

4. Manholes.

5. Handholes.

6. Cleanouts.

Q. Piping insulation shall be continuous and not interrupted by hangers and supports. Hangers shall include factory-fabricated galvanized steel insulation shields that comply with MSS-58. Insulation installed that encapsulates any part of the hanger shall be removed and reinstalled.

3.7. PENETRATIONS

A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
4. Seal jacket to roof flashing with flashing sealant.

B. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.

C. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.

1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
4. Seal jacket to wall flashing with flashing sealant.

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

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

1. Comply with requirements in Section 230500 for firestopping and fire-resistive joint sealers.

F. Insulation Installation at Floor Penetrations:

1. Pipe: Install insulation continuously through floor penetrations.
2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 230500.

3.8. 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.

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. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.

6. 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.

7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.

8. For services not specified to receive a field-applied jacket except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.

9. 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. Install removable insulation covers at locations necessary to access components. Installation shall 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 over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.

5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.9. PUMP INSULATION INSTALLATION

A. Fabricate metal boxes lined with insulation. Fit boxes around pumps and coincide box joints with splits in pump casings. Fabricate joints with outward bolted flanges. Bolt flanges on 6-inch centers, starting at corners. Install 3/8-inch diameter fasteners with wing nuts. Alternatively, secure the box sections together using a latching mechanism.

B. Fabricate boxes from aluminum, at least 0.050 inch thick.

C. For below ambient services, install a vapor barrier at seams, joints, and penetrations. Seal between flanges with replaceable gasket material to form a vapor barrier.

3.10. EQUIPMENT, TANK AND VESSEL INSULATION INSTALLATION

A. Mineral-Fiber, Pipe and Tank Insulation Installation for Tanks and Vessels: Secure insulation with adhesive and anchor pins and speed washers.

1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 50 percent coverage of tank and vessel surfaces.

2. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.

3. Protect exposed corners with secured corner angles.

4. Install adhesively attached or self-sticking insulation hangers and speed washers on sides of tanks and vessels as follows:

    a. Do not weld anchor pins to ASME-labeled pressure vessels.

    b. Select insulation hangers and adhesive that are compatible with service temperature and with substrate.

    c. On tanks and vessels, maximum anchor-pin spacing is 3 inches from insulation end joints, and 16 inches o.c. in both directions.

    d. Do not over-compress insulation during installation.

    e. Cut and miter insulation segments to fit curved sides and domed heads of tanks and vessels.

    f. Impale insulation over anchor pins and attach speed washers.

    g. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

5. Secure each layer of insulation with stainless-steel or aluminum bands. Select band material compatible with insulation materials.

6. Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch pre-stressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment approximately 6 inches from each end. Install wire or cable between two circumferential girdles 12 inches o.c. Install a wire ring around each end and around outer periphery of center openings and stretch pre-stressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional circumferential girdles along the body of equipment or tank at a minimum spacing of 48 inches o.c. Use this network for securing insulation with tie wire or bands.

7. Stagger joints between insulation layers at least 3 inches.

8. Install insulation in removable segments on equipment access doors, manholes, handholes, and other elements that require frequent removal for service and inspection.

9. Bevel and seal insulation ends around manholes, handholes, ASME stamps, and nameplates.

10. For equipment with surface temperatures below ambient, apply mastic to open ends, joints, seams, breaks, and punctures in insulation.

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

    1. Apply 100 percent coverage of adhesive to surface with manufacturer's recommended adhesive.

    2. Seal longitudinal seams and end joints.

3.11. INSTALLATION OF CELLULAR-GLASS INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with wire or bands and tighten bands without deforming insulation materials.

2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.

3. For insulation with factory-applied jackets on above-ambient services, secure laps with outward-clinched staples at 6 inches o.c.

4. For insulation with factory-applied jackets on below-ambient services, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install 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 cut sections of cellular-glass block insulation of same thickness as pipe insulation.

4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install 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.

3.12. 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.

3.13. 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. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.

3. For insulation with factory-applied jackets on above-ambient surfaces, secure laps with outward-clinched staples at 6 inches o.c.

4. For insulation with factory-applied jackets on below-ambient surfaces, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install 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, 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.

3.14. INSTALLATION OF PHENOLIC INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with tape or bands and tighten without deforming insulation materials. Orient longitudinal joints between half sections in 3- and 9-o'clock positions on the pipe.

2. For insulation with vapor barriers, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive or tape as recommended by insulation material manufacturer and seal with vapor-barrier mastic.

3. All insulation shall be tightly butted and free of voids and gaps at all joints. Vapor barrier must be continuous. Before installing jacket material, install vapor-barrier system.

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, same thickness of adjacent pipe insulation, not to exceed 1-1/2-inch thickness.

3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of phenolic block insulation of same thickness as pipe insulation.

C. Insulation Installation on Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of phenolic 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.

3.15. INSTALLATION OF POLYISOCYANURATE INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with tape or bands and tighten without deforming insulation materials. Orient longitudinal joints between half sections in 3- and 9-o'clock positions on the pipe.
2. For insulation with factory-applied jackets with vapor barriers, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive or tape as recommended by insulation material manufacturer and seal with vapor-barrier mastic.
3. All insulation shall be tightly butted and free of voids and gaps at all joints. Vapor barrier must be continuous. Before installing jacket material, install vapor-barrier system.

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, same thickness of adjacent pipe insulation, not to exceed 1-1/2-inch thickness.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polyisocyanurate block insulation of same thickness as pipe insulation.

C. Insulation Installation on Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of polyisocyanurate 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.

3.16. FIELD-APPLIED JACKET INSTALLATION

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

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

B. Where FSK jackets are indicated, install as follows:

1. Draw jacket material smooth and tight.
2. Install lap or joint strips with same material as jacket.
3. Secure jacket to insulation with manufacturer's recommended adhesive.
4. Install jacket with 1-1/2-inch laps at longitudinal seams and 3-inch wide joint strips at end joints.
5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

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

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

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

3.17. FINISHES

A. Paint pipe insulation with ASJ, cloth, or other paintable jacket material. Color shall be selected by the Owner/Engineer. Refer to Section 230553.

1. Prime with 2 coats of water-based white acrylic primer paint designed for use with associated jacket material.
2. Finish with 2 coats of flat latex paint with fungicidal agent additive to render fabric mildew proof.
3. Do not field paint PVC, stainless-steel or other non-paintable jackets.

B. Apply paint and primer at the recommended spreading rate and film thickness as recommended by the paint manufacturer.

C. Apply paint and primer within the environmental conditions recommended by the paint manufacturer but not less than 55 deg F; not more than 90 deg F; and not more than 70% RH.

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

END OF SECTION

SECTION 23 08 00 – HVAC COMMISSIONING REQUIREMENTS

PART 1 - GENERAL

1.1 DESCRIPTION

A. Commissioning

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the owner's project requirements and operational needs. The commissioning process shall encompass and coordinate the traditionally separate functions of system documentation, equipment startup, control system calibration, testing adjusting and balancing, performance testing and training. Commissioning during the construction phase is intended to achieve the following specific objectives:

1. Verify that applicable equipment and systems are installed according to the manufacturer's recommendations and to industry accepted minimum standards and that they receive adequate operational checkout by installing contractors.

2. Verify and document proper functional performance of equipment and systems.

3. Verify that O&M documentation left on site is complete.

4. Verify that the Owner's operating personnel are adequately trained.

1.2 RELATED WORK

A. Section 01 01 10 – Summary of Work

B. Section 01 03 30 – Submittal Procedures

C. Section 01 07 00 – Contract Closeout

D. Section 01 07 20 – Project Record Documents and Contractor As-Builts

E. Section 01 91 13 – General Commissioning Requirements

F. Section 23 02 00 – HVAC Systems Owner Training

G. Section 23 90 00 – BAS General Requirements

1.3 ABBREVIATIONS AND DEFINITIONS

A. A/E: Architect, Architect/Engineer, Engineer and/or Design-Builder

B. ASI: Architectural Supplemental Instruction

C. BAS: Building Automation System

D. BoD: Basis of Design. A narrative of how the designer plans to achieve the OPR.

E. CxA: Commissioning Authority

F. CC: Controls Contractor

G. CM: Construction Manager

H. Cx: Commissioning

I. Cx Plan: Commissioning Plan

J. Cx RFI: Commissioning Request for Information

K. DDC: Direct Digital Control System

L. Deficiency: A condition in the installation or function of a component, piece of equipment or system that is not in compliance with the Contract Documents and cannot be corrected in five (5) minutes time.

M. EC: Electrical Contractor

N. FBO: Furnished By Others

O. FT: Functional Performance Test

P. IAW: In Accordance With

Q. MC: Mechanical Contractor

R. O&M: Operation and Maintenance

S. OPM: Owner Project Manager

T. OPR: Owner Project Requirement. A dynamic document expressing how the owner expects the building systems to perform upon project completion.

U. PC: Prefunctional Checklist

V. RFI: Request for Information

W. Sub(s): Subcontractors or Prime Contractor

X. TAB: Test, Adjust and Balance

Y. TBD: To Be Determined

1.4 MECHANICAL EQUIPMENT AND SYSTEMS TO BE COMMISSIONED

A. Mechanical Systems

1. Building automation systems, including linkages to remote monitoring and control sites
2. Chilled water system, chilled water pumps, piping, and associated equipment.
3. Heating hot water system, associated pumps, piping, and equipment
4. Exhaust Fans.
5. Unit Heaters.
6. Ductwork.
7. Test, Adjust, and Balance of HVAC air and water systems.
8. Utility metering systems.

B. Building Automation Systems (BAS).

1. The entire BAS shall be subject to commissioning, including all hardware components, software, networking, programming and engineering services, and controls documentation.
2. Any systems connected to the BAS (monitoring or otherwise) are subject to be commissioned.

1.5 SUBMITTALS

A. Refer also to Specification Section 01 91 13, Subsection 1.7.

B. Provide the CxA a copy of the following items, for the systems to be commissioned:

1. Equipment and System Submittals to include, at minimum, the following:
   a. Equipment Data Sheets
   b. Performance data
   c. Manufacturer's pre-startup checklists
   d. Manufacturer's start-up checklists
   e. Installation Instructions
2. Test, Adjust, and Balance (TAB) Reports

a. Planning Report - TAB contractor shall submit one copy of planning report (execution plan) to the CxA for review prior to beginning TAB work. At a minimum this report should include:

1) Certifications on all instruments to be used throughout the testing. Certification must be documented within the previous 6 months.
2) Résumés and Certification of individuals who will be balancing the systems.
3) Detailed step-by-step plans for each procedure to be performed by the TAB Contractor.
4) Sample forms to be used for each measurement.

b. Initial Test Report – Prior to starting final Balance Phase, submit a copy of the initial test report (TAB punchlist) to the CxA to indicate problem areas to be resolved before final balance is completed.

c. Final Report – Submit one copy of final test report to the CxA within 7 days after fieldwork is complete.

3. Shop drawings (including any resubmittals required by the A/E)

4. Ductwork - Supply one copy of the duct leakage test results for each test section

5. Piping - Supply one copy of all of hydrostatic pressure test results

6. Initial Pre-startup and start-up plan

7. Startup Testing Report

a. Prepare startup testing report on a per system basis, documenting the results of executed testing plan.

b. Copies of all completed test forms and checklists shall be provided

c. List of all outstanding deficiencies and uncompleted items

8. Operational and maintenance documentation

9. Training plan and training materials

10. As-built documentation

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

A. Refer to Specification Section 01 91 13, Subsection 2.1.

2.2 Cx WEB-BASED COMMISSIONING TOOL

A. Refer to Specification Section 01 91 13, Subsection 2.1.

PART 3 - EXECUTION

3.1 MEETINGS

A. Refer to Specification Section 01 91 13, Subsection 3.3.

3.2 START-UP, PREFUNCTIONAL CHECKLISTS AND INITIAL CHECKOUT

A. The following procedures apply to all equipment to be commissioned, according to Section 1.4 above.

B. General

Prefunctional checklists are important to ensure that the equipment and systems are hooked up and operational. It ensures that functional performance testing (in-depth system checkout) may proceed without unnecessary delays. Each piece of equipment receives full prefunctional checkout. No sampling strategies are used. The prefunctional testing for a given system must be successfully completed prior to formal functional performance testing of equipment or subsystems of the given system.

C. Start-up and Initial Checkout Plan

1. The CxA will provide prefunctional checklists (PFCs). PFCs indicate the required procedures to be executed as part of startup and initial checkout of the systems.

2. The subcontractor responsible for providing and installing the equipment develops the full start-up plan by combining (or adding to) the CxA's prefunctional checklists with the manufacturer's detailed start-up and checkout procedures from the O&M manual and the normally used field checkout sheets. The plan will include checklists and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan.

3. The full start-up plan shall consist of:

   a. The CxA's prefunctional checklists.

   b. The manufacturer's standard written start-up procedures copied from the installation manuals with check boxes by each procedure and a signature block added by hand at the end

   c. The manufacturer's normally used field checkout sheets

d. Specifically, the mechanical start-up plan shall also include the contractors TAB plan.

4. The contractor submits the full startup plan to the CxA for review and approval.

5. The CxA reviews and approves the procedures and the format for documenting them, noting any plans that need to be added.

D. Execution of Prefunctional Checklists and Startup

1. Two weeks prior to startup, the Subs and vendors schedule startup and checkout with the OPM, CM and CxA. The performance of the prefunctional checklists, startup and checkout are directed and executed by the Sub or vendor. When checking off prefunctional checklists, signatures may be required of other Subs for verification of completion of their work.

2. The CxA and possibly the A/E will observe the procedures for selected pieces of primary equipment.

3. The CxA will observe the physical start-up of all major systems.

4. The CxA will witness piping cleanout procedures and verify any required water or lab tests.

5. For lower-level components of equipment, (e.g., VAV boxes, sensors, controllers), the CxA will observe a sampling of the prefunctional and start-up procedures.

6. The Subs and vendors shall execute startup and provide the CM with a signed and dated copy of the completed start-up and prefunctional tests and checklists. The CM reviews for completion and accuracy, then submits to the CxA.

7. Only individuals that have direct knowledge and witnessed that a line item task on the prefunctional checklist was actually performed shall initial or check that item off. It is not acceptable for witnessing supervisors to fill out these forms.

8. Completed startup test report must be provided to CxA prior to functional testing.

E. Deficiencies, Non-Conformance and Approval in Checklists and Startup

1. The Subs shall clearly list any outstanding items of the initial start-up and prefunctional procedures that were not completed successfully. The procedures form and any outstanding deficiencies shall be provided to the CxA within two days of test completion.

2. The CxA will work with the Subs and vendors to determine what is required to correct outstanding deficiencies and retest deficiencies of uncompleted items. The CxA will involve the PM and others as necessary. The installing Subs or vendors shall correct all areas that are deficient or incomplete in the checklists and tests in a timely manner, and shall notify the CxA as soon as outstanding items have been corrected.

3. Items left incomplete, which later cause deficiencies or delays during functional testing may result in backcharges to the responsible party. Refer to Section 01 91 13, 3.3 – Documentation, Non-Conformance and Approval of Tests.

3.3 FUNCTIONAL PERFORMANCE TESTING

A. This sub-section applies to functional testing and demonstration for equipment and system in this division.

B. The general list of equipment and systems to be commissioned is found in section 1.4.

C. Objectives and Scope

1. The objective of functional performance testing is to demonstrate that each system is operating according to the owner's project requirements, documented project program, and Contract Documents. Functional testing facilitates bringing the systems from a state of substantial completion to full dynamic operation. Additionally, during the testing process, areas of deficient performance are identified and corrected, improving the operation and function of the systems.

2. In general, each system shall be operated through all modes of operation where there is a specified system response.

3. Testing proceeds from components to subsystems to systems. When the proper performance of all interacting individual systems has been achieved, the interface or coordinated responses between systems is checked.

4. The contractor shall supply all personnel and equipment for the demonstration, including, but not limited to, tools, instruments, ladders, lifts, computers, software, cables, etc. Contractor supplied personnel must be competent with and knowledgeable of all project-specific systems, and automation hardware and software. All training documentation, submittals, installation manuals, and O&Ms, shall be at the job site before functional testing commences.

D. Development of Test Procedures

1. The CxA develops specific functional test procedures and forms to verify and document proper operation of each piece of equipment and system. The CxA provides a copy of the test procedures to the A/E, OPM and installing Sub who shall review the tests prior to testing. The A/E and Sub(s) shall point out to the CxA any specific problems as related to feasibility, safety, equipment and warranty protection.

E. Coordination and Scheduling

1. The CM shall provide sufficient notice to the CxA regarding the Subs completion schedule for the prefunctional checklists and startup of all equipment and systems. The CxA will schedule functional tests after written notification from the CM and affected

Subs. Completed startup testing report must be provided to CxA prior to functional testing. The CxA shall direct, witness and document the functional testing of all equipment and systems. The Subs shall execute the tests.

2. In general, functional testing shall not be scheduled until all hardware and software submittals are approved, Prefunctional checklists are approved, and start-up has been satisfactorily completed. Further, mechanical system functional testing shall not be scheduled until the final TAB report is approved and all reported deficiencies by TAB firm are corrected. Scheduling of functional testing shall be done with a minimum of two week notice prior to testing. Functional testing of the equipment and systems listed in section 1.4 of this specification section shall not be conducted out of the presence of the CxA and OPM, unless specifically approved to do so in writing by the CxA or OPM. Any functional testing which occurs outside the presence of the CxA or OPM without written authorization to do so will be required to be re-tested at no expense to the owner.

F. Test Methods

1. Functional performance testing and verification may be achieved by manual testing (persons manipulate the equipment and observe performance) or by monitoring the performance and analyzing the results using the control system's trend log capabilities or by stand-alone dataloggers.

2. Simulated Conditions. Simulating conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.

3. Overwritten Values. Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system to be something other than it really is, shall be allowed, but shall be used with caution and avoided when possible. Such testing methods often can only test a part of a system, as the interactions and responses of other systems will be erroneous or not applicable. Simulating a condition is preferable. e.g., for the above case, by heating the outside air sensor with a hair dryer rather than overwriting the value or by altering the appropriate setpoint to see the desired response. Before simulating conditions or overwriting values, sensors, transducers and devices shall have been calibrated.

4. Simulated Signals. Using a signal generator which creates a simulated signal to test and calibrate transducers and DDC constants is generally recommended over using the sensor to act as the signal generator via simulated conditions or overwritten values.

5. Altering Setpoints. Rather than overwriting sensor values, and when simulating conditions is difficult, altering setpoints to test a sequence is acceptable. For example, to see the AC compressor lockout work at an outside air temperature below 55ºF, when the outside air temperature is above 55ºF, temporarily change the lockout setpoint to be 2ºF above the current outside air temperature.

6. Indirect Indicators. Relying on indirect indicators for responses or performance shall be allowed only after visually and directly verifying and documenting, over the range of the tested parameters, that the indirect readings through the control system represent actual

conditions and responses. Much of this verification is completed during prefunctional testing.

7. Setup. Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Sub executing the test shall provide all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. necessary to execute the test according to the specified conditions. At completion of the test, the Sub shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.

G. Demonstration, Verification and Validation

1. TAB Validation

a. The air balancing and water balancing is de-bugged, completed and approved before the CxA completes a TAB validation of air-related and water-related equipment or systems. The CxA will direct a TAB checkout by verifying the values reported in the final TAB report. The contractor shall supply all personnel and equipment for the checkout, including, but not limited to, tools, instruments, ladders, lifts, computers, software, cables, etc. The TAB verification shall verify:

1) grilles, diffusers, and registers

2) terminal devices

3) all main HVAC systems

4) general exhaust fans

5) hydronic systems (e.g. HW/CHW) equipment and distribution components

2. Metering System

a. Demonstrate meters are calibrated in accordance with the manufacturer's published data approved.
b. Demonstrate accuracy of all meters.
c. Demonstrate utility monitoring integration with BAS.

H. Problem Solving

1. The CxA will recommend solutions to problems found, however the burden of responsibility to solve, correct and retest problems is with the CM, Subs and A/E.

3.4 DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS

A. Refer to Specification Section 01 91 13, Subsection 3.7.

3.5 OPERATION AND MAINTENANCE MANUALS

A. In addition to Installation manuals, the contractor shall provide one copy of the Operation and Maintenance Manuals to the CxA for the systems to be commissioned. The O&M Manuals shall be provided to the CxA at least 8 weeks prior to the start of Functional Testing. O&M Manuals shall be in electronic form, the file format shall be Adobe Acrobat readable document. The document shall be formatted to include level 1 bookmarks that link to each main section of equipment. Refer to specification section 01 91 13, subsection 3.8 for further detail.

B. Refer to specification section 01 91 13, Subsection 3.8 for further details.

3.6 TRAINING OF OWNER PERSONNEL

A. See Specification Section 01 91 13, Subsection 3.9.

B. CxA shall document the completion of comprehensive Owner training. Training shall include the understanding of the systems and the operation and maintenance of each major piece of HVAC equipment or system.

C. Training shall include classroom sessions, if necessary, followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including AHUs, pumps, VAV terminals, VFDs, etc.

3.7 DEFERRED TESTING

A. See Specification Section 01 91 13, Subsection 3.10.

END OF SECTION 230800

SECTION 23 11 26 – FUEL GAS PIPING

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes piping, fittings, specialties, valves, and pressure regulators for fuel gas piping systems.

1.2. DEFINITIONS

A. LPG or LP-Gas: Liquefied-petroleum gas.

1.3. SUBMITTALS

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

B. Close-Out Submittals:

1. Operation and Maintenance Data: For LPG pipe, risers, motorized gas valves, and pressure regulators to include in emergency, operation, and maintenance manuals.

1.4. FIELD CONDITIONS

A. Interruptions of Existing LP Gas Service: Do not interrupt LP gas service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary service according to requirements indicated:

1. Notify Owner no fewer than two days in advance of proposed interruption of fuel gas service.

2. Do not interrupt LP gas service without Owner's written permission.

1.5. COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

B. Coordinate requirements for access panels and doors for valves installed concealed behind finished surfaces.

PART 2 - PRODUCTS

2.1. PERFORMANCE REQUIREMENTS

A. Minimum Operating-Pressure Ratings:

1. For LPG piping containing only vapor:

a. Piping and Valves: 125 psig minimum unless otherwise indicated.

b. Service Regulators: 125 psig minimum unless otherwise indicated.

B. LPG System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 2.0 psig but not more than 5.0 psig, and is reduced to secondary pressure of more than 0.5 psig, but not more than 2.0 psig.

2.2. PIPES, TUBES, AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.

1. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.

2. Wrought-Steel Welding Fittings: ASTM A 234/A 234M for butt welding and socket welding.

3. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.

4. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, minimum Class 150, including bolts, nuts, and gaskets of the following material group, end connections, and facings:

a. Material Group: 1.1.

b. End Connections: Threaded or butt welding to match pipe.

c. Lapped Face: Not permitted underground.

d. Gasket Materials: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound met-al gaskets.

e. Bolts and Nuts: ASME B18.2.1, carbon steel aboveground and stainless steel underground.

B. PE Pipe: ASTM D 2513, SDR 11.

1. PE Fittings: ASTM D 2683, socket-fusion type or ASTM D 3261, butt-fusion type with dimensions matching PE pipe.

2. Anodeless Service-Line Risers: Factory-fabricated and leak tested.

a. Underground Portion: PE pipe complying with ASTM D 2513, SDR 11 inlet.

b. Casing: Steel pipe complying with ASTM A 53/A 53M, Schedule 40, black steel, Type E or S, Grade B, with corrosion-protective coating covering. Vent casing aboveground.

c. Aboveground Portion: PE transition fitting.

d. Outlet shall be threaded or flanged or suitable for welded connection.

e. Tracer wire connection.

f. Ultraviolet shield.

g. Stake supports with factory finish to match steel pipe casing or carrier pipe.

2.3. PIPING SPECIALTIES

A. Appliance Flexible Connectors:

1. Indoor, Fixed-Appliance Flexible Connectors: Comply with ANSI Z21.24.
2. Indoor, Movable-Appliance Flexible Connectors: Comply with ANSI Z21.69.
3. Outdoor, Appliance Flexible Connectors: Comply with ANSI Z21.75.
4. Corrugated stainless-steel tubing with polymer coating.
5. Operating-Pressure Rating: 0.5 psig.
6. End Fittings: Zinc-coated steel.
7. Threaded Ends: Comply with ASME B1.20.1.
8. Maximum Length: 72 inches

B. Quick-Disconnect Devices: Comply with ANSI Z21.41.

1. Copper-alloy convenience outlet and matching plug connector.
2. Nitrile seals.
3. Hand operated with automatic shutoff when disconnected.
4. For indoor or outdoor applications.
5. Adjustable, retractable restraining cable.

C. Y-Pattern Strainers:

1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.
3. Strainer Screen: 60-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 125 psig.

D. T-Pattern Strainers:

1. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
2. End Connections: Grooved ends.
3. Strainer Screen: 60-mesh startup strainer, and perforated stainless-steel basket with 57 percent free area.
4. CWP Rating: 750 psig.

E. Weatherproof Vent Cap: Cast- or malleable-iron increaser fitting with corrosion-resistant wire screen, with free area at least equal to cross-sectional area of connecting pipe and threaded-end connection.

2.4. JOINING MATERIALS

A. Joint Compound and Tape: Suitable for LPG service.

B. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

2.5. MANUAL GAS SHUTOFF VALVES

A. See "Aboveground Manual Gas Shutoff Valve Schedule" Article for where each valve type is applied in various services.

B. General Requirements for Metallic Valves, NPS 2 and Smaller: Comply with ASME B16.33.

1. CWP Rating: 125 psig.
2. Threaded Ends: Comply with ASME B1.20.1.
3. Dry-Seal Threads on Flare Ends: Comply with ASME B1.20.3.
4. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
5. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction for valves 1 inch and smaller.
6. Service Mark: Valves 1-1/4 inches to NPS 2 shall have initials "WOG" permanently marked on valve body.

C. General Requirements for Metallic Valves, NPS 2-1/2 and Larger: Comply with ASME B16.38.

1. CWP Rating: 125 psig.
2. Flanged Ends: Comply with ASME B16.5 for steel flanges.
3. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
4. Service Mark: Initials "WOG" shall be permanently marked on valve body.

D. One-Piece, Bronze Ball Valve with Bronze Trim: MSS SP-110.

1. Body: Bronze, complying with ASTM B 584.
2. Ball: Chrome-plated brass.
3. Stem: Bronze; blowout proof.

4. Seats: Reinforced TFE; blowout proof.

5. Packing: Separate packnut with adjustable-stem packing threaded ends.

6. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.

7. CWP Rating: 600 psig.

8. Listing: Valves NPS 1 and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.

9. Service: Suitable for LPG service with "WOG" indicated on valve body.

E. Two-Piece, Full-Port, Bronze Ball Valves with Bronze Trim: MSS SP-110.

1. Body: Bronze, complying with ASTM B 584.

2. Ball: Chrome-plated bronze.

3. Stem: Bronze; blowout proof.

4. Seats: Reinforced TFE; blowout proof.

5. Packing: Threaded-body packnut design with adjustable-stem packing.

6. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.

7. CWP Rating: 600 psig.

8. Listing: Valves NPS 1 and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.

9. Service: Suitable for LPG service with "WOG" indicated on valve body.

2.6. MOTORIZED GAS VALVES

A. Electrically Operated Valves: Comply with UL 429.

1. Pilot operated.

2. Body: Brass or aluminum.

3. Seats and Disc: Nitrile rubber.

4. Springs and Valve Trim: Stainless steel.

5. 120-V ac, 60 Hz, Class B, continuous-duty molded coil, and replaceable.

6. NEMA ICS 6, Type 4, coil enclosure.

7. Normally closed.

8. Visual position indicator.

2.7. PRESSURE REGULATORS

A. General Requirements:

1. Single stage and suitable for LPG.
2. Steel jacket and corrosion-resistant components.
3. Elevation compensator.
4. End Connections: Threaded for valves 2-inches NPS and smaller; flanged for valves 2 1/2-inches NPS and larger.

B. Service Pressure Regulators: Comply with ANSI Z21.80.

1. Body and Diaphragm Case: Cast iron or die-cast aluminum.
2. Springs: Zinc-plated steel; interchangeable.
3. Diaphragm Plate: Zinc-plated steel.
4. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
5. Orifice: Aluminum; interchangeable.
6. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
7. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
8. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.
9. Overpressure Protection Device: Factory mounted on pressure regulator.
10. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
11. Maximum Inlet Pressure: 100 psig.

C. Line Pressure Regulators: Comply with ANSI Z21.80.

1. Body and Diaphragm Case: Cast iron or die-cast aluminum.
2. Springs: Zinc-plated steel; interchangeable.
3. Diaphragm Plate: Zinc-plated steel.
4. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
5. Orifice: Aluminum; interchangeable.
6. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.

7. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.

8. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.

9. Overpressure Protection Device: Factory mounted on pressure regulator.

10. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.

11. Maximum Inlet Pressure: 10 psig.

D. Appliance Pressure Regulators: Comply with ANSI Z21.18.

1. Body and Diaphragm Case: Die-cast aluminum.

2. Springs: Zinc-plated steel; interchangeable.

3. Diaphragm Plate: Zinc-plated steel.

4. Seat Disc: Nitrile rubber.

5. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.

6. Factory-Applied Finish: Minimum three-layer polyester and polyurethane paint finish.

7. Regulator may include vent limiting device, instead of vent connection, if approved by authorities having jurisdiction.

8. Maximum Inlet Pressure: 5 psig.

2.8. LABELING AND IDENTIFYING

A. Detectable Warning Tape: Acid- and alkali-resistant, PE film warning tape manufactured for marking and identifying underground utilities, a minimum of 6 inches wide and 4 mils thick, continuously in-scribed with a description of utility, with metallic core encased in a protective jacket for corrosion protection, detectable by metal detector when tape is buried up to 30 inches deep; colored yellow.

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine roughing-in for LPG piping system to verify actual locations of piping connections be-fore equipment installation.

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

3.2. PREPARATION

A. Close equipment shutoff valves before turning off LP-gas to premises or piping section.

B. Inspect LP piping according to NFPA 58 and the 2018 Virginia Fuel Gas Code to determine that LP utilization devices are turned off in piping section affected.

C. Comply with NFPA 58 and the 2018 Virginia Fuel Gas Code requirements for prevention of accidental ignition.

3.3. OUTDOOR PIPING INSTALLATION

A. Comply with NFPA 58 and the 2018 Virginia Fuel Gas Code for installation and purging of LP piping.

B. Install underground, LPG piping buried at least 36 inches below finished grade. Comply with requirements in Section 230300 and Division 31 for excavating, trenching, and backfilling.

1. If LPG piping is installed less than 36 inches below finished grade, install it in protective shielding conduit. LPG piping shall never be installed less than 1-inches below finished grade.

C. Install underground, PE, LPG piping according to ASTM D 2774.

D. Steel Piping with Protective Coating:

1. Apply joint cover kits to pipe after joining to cover, seal, and protect joints.

2. Replace pipe having damaged PE coating with new pipe.

E. Install fittings for changes in direction and branch connections.

F. Install pressure gage upstream and downstream from each service regulator. Pressure gages are specified in Section 230519.

3.4. INDOOR PIPING INSTALLATION

A. Comply with the 2018 Virginia Fuel Gas Code and NFPA 58 for installation and purging of LPG piping.

B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

C. Arrange for pipe spaces, chases, slots, sleeves, and openings in building structure during progress of construction, to allow for mechanical installations.

D. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

E. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

F. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

G. Locate valves for easy access.

H. Install LPG piping at uniform grade of 2 percent down toward drip and sediment traps.

I. Install piping free of sags and bends.

J. Install fittings for changes in direction and branch connections.

K. Verify final equipment locations for roughing-in.

L. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.

M. Drips and Sediment Traps: Install drips at points where condensate may collect, including service-meter outlets. Locate where accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.

N. Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Use nipple a minimum length of 3 pipe diameters, but not less than 3 inches long and same size as connected pipe. Install with space below bottom of drip to remove plug or cap.

O. Extend relief vent connections for service regulators, line regulators, and overpressure protection devices to outdoors and terminate with weatherproof vent cap.

P. Conceal pipe installations in walls, pipe spaces, utility spaces, above ceilings, below grade or floors, and in floor channels unless indicated to be exposed to view.

Q. Concealed Location Installations: Except as specified below, install concealed LPG piping and piping installed under the building in containment conduit constructed of steel pipe with welded joints as described in Part 2. Install a vent pipe from containment conduit to outdoors and terminate with weatherproof vent cap.

1. Above Accessible Ceilings: LPG piping, fittings, valves, and regulators may be installed in accessible spaces without protective containment conduit.

2. In Floors: Install LPG piping with welded or brazed joints and protective coating in cast-in-place concrete floors. Cover piping to be cast in concrete slabs with minimum of 1-1/2 inches of concrete. Piping may not be in physical contact with other metallic structures such as reinforcing rods or electrically neutral conductors. Do not embed piping in concrete slabs containing quick-set additives or cinder aggregate.

3. In Floor Channels: Install LPG piping in floor channels. Channels must have cover and be open to space above cover for ventilation.

4. In Walls or Partitions: Protect tubing installed inside partitions or hollow walls from physical damage using steel striker barriers at rigid supports.

   a. Exception: Tubing passing through partitions or walls does not require striker barriers.

5. Prohibited Locations:

   a. Do not install LPG piping in or through circulating air ducts, clothes or trash chutes, chimneys or gas vents (flues), ventilating ducts, or dumbwaiter or elevator shafts.

   b. Do not install LPG piping in solid walls or partitions.

R. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.

S. Connect branch piping from top or side of horizontal piping.

T. Install unions in pipes NPS 2 and smaller, adjacent to each valve, at final connection to each piece of equipment. Unions are not required at flanged connections.

U. Do not use LPG piping as grounding electrode.

V. Install strainer on inlet of each line-pressure regulator and automatic or electrically operated valve.

W. Install pressure gage [downstream] [upstream and downstream] from each line regulator. Pressure gages are specified in Section 230519.

X. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517.

Y. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517.

Z. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230100.

3.5. VALVE INSTALLATION

A. Install manual gas shutoff valve for each gas appliance ahead of corrugated stainless-steel tubing, aluminum, or copper connector.

B. Install underground valves with valve boxes.

C. Install regulators and overpressure protection devices with maintenance access space adequate for servicing and testing.

D. Install earthquake valves aboveground outside buildings according to listing.

E. Install anode for metallic valves in underground PE piping.

3.6. PIPING JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs.

B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

C. Threaded Joints:

1. Thread pipe with tapered pipe threads complying with ASME B1.20.1.
2. Cut threads full and clean using sharp dies.
3. Ream threaded pipe ends to remove burrs and restore full inside diameter of pipe.

4. Apply appropriate tape or thread compound to external pipe threads unless dry-seal threading is specified.

5. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

D. Welded Joints:

1. Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators.

2. Bevel plain ends of steel pipe.

3. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.

E. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.

1. Plain-End Pipe and Fittings: Use butt fusion.

2. Plain-End Pipe and Socket Fittings: Use socket fusion.

3.7. HANGER AND SUPPORT INSTALLATION

A. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices specified in Section 230548.

B. Comply with requirements for pipe hangers and supports specified in Section 230529.

C. Install hangers for horizontal steel piping with maximum spacing and minimum rod sizes that comply with Section 230529 and drawing details.

D. Install hangers for horizontal drawn-temper copper tubing with maximum spacing and minimum rod sizes that comply with Section 230529.

E. Install hangers for horizontal, corrugated stainless-steel tubing with the following maximum spacing and minimum rod sizes:

1. Piping 3/8-inch NPS: Maximum span, 4 feet; minimum rod size, 3/8 inch.

2. Piping 1/2-inch NPS: Maximum span, 6 feet; minimum rod size, 3/8 inch.

3. Piping 3/4-inch NPS and larger: Maximum span, 8 feet; minimum rod size, 3/8 inch.

3.8. CONNECTIONS

A. Connect to LPG utility supplier’s gas main according to utility's procedures and requirements.

B. Install LPG piping electrically continuous and bonded to gas appliance equipment grounding conductor of the circuit powering the appliance according to NFPA 70.

C. Install piping adjacent to appliances to allow service and maintenance of appliances.

D. Connect piping to appliances using manual gas shutoff valves and unions. Install valve within 72 inches of each LP gas-fired appliance and equipment. Install union between valve and appliances or equipment.

E. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.

3.9. LABELING AND IDENTIFYING

A. Comply with requirements in Section 230553 for piping and valve identification.

3.10. FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Test, inspect, and purge LPG systems according to NFPA 58, the 2018 Virginia Fuel Gas Code, and authorities having jurisdiction.

B. Prepare test and inspection reports.

3.11. OUTDOOR PIPING SCHEDULE

A. Underground LPG vapor piping shall be the following:

1. PE pipe and fittings joined by heat fusion, or mechanical couplings; service-line risers with tracer wire terminated in an accessible location.

B. Aboveground LPG piping shall be the following:

1. Steel pipe with malleable-iron fittings and threaded joints.

3.12. INDOOR PIPING SCHEDULE FOR SYSTEM PRESSURES LESS THAN 5.0 PSIG

A. Aboveground, branch piping 1-inch NPS and smaller shall be the following:

1. Steel pipe with malleable-iron fittings and threaded joints.

B. Aboveground, distribution piping shall be the following:

1. Steel pipe with malleable-iron fittings and threaded joints.
2. Steel pipe with wrought-steel fittings and welded joints.

C. Underground, below building, piping shall be the following:

1. Not allowed.

D. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.

E. Containment Conduit Vent Piping: Steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.

3.13. ABOVEGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

A. Valves for pipe sizes 2-inches NPS and smaller at second-stage pressure regulator assemblies shall be the following:

1. One-piece, bronze ball valve with bronze trim and tamper-resistant wrench-tab operator with lock ring.

B. Distribution piping valves for pipe sizes 2-inches NPS and smaller shall be the following:

1. One-piece, bronze ball valve with bronze trim.

C. Valves in branch piping for single appliance shall be the following:

1. One-piece, bronze ball valve with bronze trim.

END OF SECTION

SECTION 23 21 13 – HYDRONIC PIPING

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes pipe and fitting materials and joining methods for above ground hydronic piping.

1.2. SUBMITTALS

A. Delegated Design Submittals:

1. Design calculations and detailed fabrication and assembly of pipe anchors and alignment guides, hangers and supports for multiple pipes, expansion joints and loops, and attachments of the same to the building structure.

2. Locations of pipe anchors and alignment guides and expansion joints and loops.

3. Locations of and details for penetrations, including sleeves and sleeve seals for exterior walls, floors, basement, and foundation walls.

B. Qualification Submittals:

1. Welding certificates.

2. Pipe and fitting manufacturing source list confirming the materials will be products of the United States of America.

C. Product Submittals: For each type of product indicated.

1.3. QUALITY ASSURANCE

A. Installer Qualifications:

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

2. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

a. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.

b. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

B. <u>All piping and fittings shall be products of the United States of America</u>. All other piping and fittings will be removed from the project at the contractor's expense.

1. This requirement does not apply to piping that is internal to and factory-fabricated and installed in unitary equipment. The requirement does apply to all field-installed piping and skid-mounted assemblies with factory-fabricated and installed piping.

PART 2 - PRODUCTS

2.1. PERFORMANCE REQUIREMENTS

A. Hydronic piping and components shall be capable of withstanding the following working pressures and temperatures. Piping systems shall be pressure tested, leak tested and flushed according to Section 230555 based on these working pressures.

1. Chilled Water Piping: 100 psig at 75 deg F.
2. Heating (140 to 200 deg F) Water Piping: 100 psig at 250 deg F.
3. Make-Up (Domestic) Water Piping: 80 psig at 75 deg F.

2.2. COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type L.

B. Annealed-Temper Copper Tubing: ASTM B 88, Type K.

C. DWV Copper Tubing: ASTM B 306, Type DWV.

D. Wrought-Copper Fittings and Unions: ASME B16.22.

2.3. STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53 or A 106, black carbon steel with plain ends; ERW electric resistance welded (Type E) or seamless (Type S), Grade B. Refer to Part 3 for applications.

1. "Standard Weight" steel piping is not equal to Schedule 40 at 12-inches NPS and larger. Provide piping materials that comply with Part 3 of this section. The following are the minimum pipe thicknesses for each application:

STEEL PIPE WALL THICKNESSES			
NOMINAL PIPE SIZE (INCHES)	STD. WEIGHT WALL THICKNESS (INCHES)	SCHEDULE 40 WALL THICKNESS (INCHES)	SCHEDULE 80 WALL THICKNESS (INCHES)
3/4	0.113	0.113	0.154
1	0.133	0.133	0.179
1 1/4	0.140	0.140	0.191
1 1/2	0.145	0.145	0.200
2	0.154	0.154	0.218
2 1/2	0.203	0.203	0.276
3	0.216	0.216	0.300

4	0.237	0.237	0.337
6	0.280	0.280	0.432
8	0.322	0.322	0.500
10	0.365	0.365	0.594
12	0.375	0.406	0.688
14	0.375	0.438	0.750
16	0.375	0.500	0.844
18	0.375	0.562	0.938
20	0.375	0.594	1.031
24	0.375	0.688	1.219

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250.

C. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300.

D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300.

E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 125 and 250; raised ground face, and bolt holes spot faced.

F. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.

G. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of material group 1.1, butt-welded end connections, and raised facings.

H. Steel Pipe Nipples: ASTM A 733, made of same materials and wall thicknesses as pipe in which they are installed.

2.4. JOINING MATERIALS

A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless otherwise indicated. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, Grade B7, 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 D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

E. Gasket Material: Thickness, material, and type suitable for fluid to be handled and working temperatures and pressures.

2.5. DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating non-conductive insulating material. Include end connections compatible with pipes to be joined.

B. Dielectric Unions, 2-inches NPS and smaller: Factory-fabricated ASSE 1079 rated for 150 psig with solder-joint copper alloy and threaded ferrous end connections.

C. Dielectric Flanges, 1 1/2 to 4-inches NPS: Factory-fabricated ASSE 1079 bolted, companion-flange assembly, rated for 150 psig with solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous end connections.

D. Dielectric Nipples, 4-inches NPS and smaller: Factory-fabricated IAPMO PS 66 electro-plated steel nipple complying with ASTM F 1545, inert and non-corrosive propylene, rated for 300 psig, and threaded end connections

PART 3 - EXECUTION

3.1. PIPING APPLICATIONS

A. Heating and Cooling Water Piping, Above Ground, 2-inches NPS and smaller:

1. Copper Piping: Type L, drawn-temper (“hard”) copper tubing, wrought-copper fittings and soldered joints.

B. Heating and Cooling Water Piping, Above Ground, 2 1/2-inches NPS and larger:

1. Steel Piping: Schedule 40, Type E or S, Grade B steel, Class 150 wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and butt-welded and flanged joints.

C. Make-Up (Domestic) Water Piping, Above Ground:

1. Copper Piping: Type L, drawn-temper (“hard”) copper tubing, wrought-copper fittings and soldered joints.

D. Make-Up (Domestic) Water Piping, Below Slab:

1. Copper Piping: Type K, annealed-temper (“soft”) copper tubing, wrought-copper fittings, and soldered joints. No joints shall be located below grade.

E. Condensate Drain Piping:

1. Copper Piping: Type DWV for 1 1/2-inch and larger piping and Type L for 1 1/4-inch and smaller piping, drawn-temper (“hard”) copper tubing, wrought-copper fittings and soldered joints.

F. Blowdown-Drain Piping: Same materials and joining methods as for piping specified for the service in which blowdown drain is installed.

G. Air-Vent Piping: Type K, annealed-temper (“soft”) copper tubing, wrought-copper fittings, and soldered joints.

H. Safety-Valve Inlet and Outlet Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed.

3.2. PIPING INSTALLATIONS

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. 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, line-size full port-ball valve, and short line-size nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

    1. Piping 6-inches NPS and smaller: 3/4-inch

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow, except drain piping. For drain piping provide a uniform grade of 0.2 percent downward 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 Section 232119.

Q. Install unions in piping, 2-inch NPS and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

R. Install flanges in piping, 2 1/2-inch NPS and larger, at final connections of equipment and elsewhere as indicated.

S. Install shutoff valve immediately upstream of each dielectric fitting.

T. Comply with requirements in Section 230516 for installation of expansion loops, expansion joints, anchors, and pipe alignment guides.

U. Comply with requirements in Section 230553 for identifying piping.

V. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 230517.

W. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 230517.

X. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 230100.

Y. Install pressure / temperature ports as indicated in the details and on the inlet and discharge side of each balancing and control valve.

Z. Utilize wet taps or line stops to connect to existing active piping.

3.3. DIELECTRIC FITTING INSTALLATION

A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.

3.4. HANGERS AND SUPPORTS

A. Comply with requirements in Section 230529 for hanger, support, and anchor devices. Comply with the following requirements for maximum spacing of supports.

B. Comply with requirements in Section 230548 for seismic restraints.

3.5. PIPE JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

C. 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.

D. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8/A5.8M.

E. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

F. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.

G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

3.6. 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 bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.

D. Install ports for pressure gages and thermometers at coil inlet and outlet connections. Comply with requirements in Section 230519.

3.7. FIELD QUALITY CONTROL

A. Inspect welds in accordance with Section 230100.

B. Flush, leak test and pressure test piping in accordance with Section 230555.

C. Perform the following before operating the system:

1. Open manual valves fully.
2. Inspect pumps for proper rotation.
3. Set makeup pressure-reducing valves for required system pressure.
4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Inspect and set operating temperatures of hydronic equipment, such as boilers, chillers, cooling towers, to specified values.
7. Verify lubrication of motors and bearings.

END OF SECTION

SECTION 23 21 16 – HYDRONIC PIPING SPECIALTIES

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes special-duty valves and specialties for hydronic piping systems.

1.2. SUBMITTALS

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

1. Valves: Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.

2. Air-control devices.

3. Hydronic specialties.

B. Close-Out Submittals:

1. Operation and Maintenance Data: For air-control devices, hydronic specialties, and special-duty valves to include in emergency, operation, and maintenance manuals.

1.3. QUALITY ASSURANCE

A. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

PART 2 - PRODUCTS

2.1. MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide specialty valves, air vents, tanks and strainers by the following, unless otherwise noted below:

1. Amtrol

2. Armstrong

3. Bell & Gossett

4. TACO

2.2. PRESSURE REDUCING VALVES

A. Diaphragm-Operated, Pressure-Reducing Valves: Bronze or brass body diaphragm-operated pressure reducing valves with PTFE disc, brass seat, EPT diaphragm, EPDM O-ring stem seals, low inlet pressure check valve, inlet strainer that is removable without system shutdown and non-corrosive valve seat and stem and ASME labeled. Valve size, capacity and operating pressure shall be selected to suit system. Operating pressure and capacity shall be factory-set and field adjustable.

2.3. SAFETY RELIEF VALVES

A. Diaphragm-Operated Safety Relief Valves: Bronze or brass body diaphragm-operated safety relief valves with PTFE disc, brass seat, EPT diaphragm, EPDM O-ring stem seals, brass and rubber internal wetted working parts, inlet strainer that is removable without system shutdown and non-corrosive valve seat and stem and ASME labeled. Valve size, capacity and operating pressure shall be selected to suit system. Operating pressure and capacity shall be factory-set and field adjustable.

2.4. AIR-CONTROL DEVICES

A. Manual Air Vents: Manual air vent with bronze body, non-ferrous internal parts, screwdriver or thumbscrew operator, 1/2-inch NPS inlet connection and 1/8-inch outlet connection and rated for 150 psig CWP (cold working pressure) and up to 225 deg F operating temperature.

B. Automatic Air Vents: Automatic air vent with bronze body, non-ferrous internal parts, non-corrosive metal float operator, 3/4-inch NPS inlet connection and 1/4-inch outlet connection and rated for 150 psig CWP (cold working pressure) and up to 240 deg F operating temperature.

C. Bladder Expansion Tanks: Factory-fabricated welded steel bladder-type expansion tank with taps for pressure gage, air charge fitting and drain fitting. Tanks shall be rated for 125 psig working pressure and 240 deg F maximum operating temperature and labeled according to ASME Boiler and Pressure Vessel Code Section VIII, Division 1. Amtrol ‘L/LBC’ Series, Bell & Gossett ‘B’ Series, or Taco ‘CA’ Series.

1. Bladder: Securely sealed into tank to separate air charge from system water to maintain required expansion capacity.

2. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.

D. Tangential-Type Air Separators: Factory-fabricated welded steel tangential-type air separators with perforated stainless steel air collector tube; threaded inlet and outlet connections for 2-inch NPS and smaller and flanged for 2 1/2-inch and larger; and threaded blowdown connection. Separators shall be rated for 125 psig working pressure and 350 deg F maximum operating temperature and ASME labeled. Separators shall be sized for maximum system flow or larger as scheduled. Bell & Gossett Rolairtrol series, Spirotherm Spirovent Air VSR series or TACO ACT series.

1. Strainer: None.

2.5. BUFFER TANKS

A. Description: Factory-fabricated welded-steel buffer tanks for service indicated on drawings, with ring base, flanged inlet and outlet piping connections, drain tapping and air vent tapping. Tanks shall be rated for 125 psig working pressure and 375 deg F maximum operating temperature and labeled according to ASME Boiler and Pressure Vessel Code Section VIII, Division 1. Tanks 42-inches diameter or larger shall have manhole. Amtrol ‘CWBT/HWBT’ series, Cemline ‘CWB’ series, or TACO ‘BTH/BTL’ series.

1. Chilled Water: Tanks shall include divider baffle to promote water mixing.

2.6. HYDRONIC PIPING SPECIALTIES

A. Y-Pattern Strainers: Y-pattern strainer with cast-iron body, bolted cover and bottom drain connection; threaded end connections for 2-inch NPS and smaller and flanged for 2 1/2-inch and larger; medium-straining mesh stainless steel strainer screen; and rated for 125 psig CWP (cold working pressure).

B. Basket Strainers: Basket strainers with cast-iron body, bolted cover and bottom drain connection; threaded end connections for 2-inch NPS and smaller and flanged for 2 1/2-inch and larger; fine-straining mesh stainless steel start-up strainer; medium-straining perforated stainless steel basket with 50-percent free area; and rated for 125 psig CWP (cold working pressure).

C. Stainless-Steel Bellow Flexible Connectors: Flexible connector constructed of stainless steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket; capable of 3/8-inch misalignment; threaded end connections for 2-inch NPS and smaller and flanged for 2 1/2-inch and larger; and rated for 150 psig CWP (cold working pressure) and 250 deg F maximum operating temperature. Flexicraft FF/TT series or Engineer approved equal.

2.7. ESCUTCHEONS AND FLOOR PLATES

A. Escutcheons:

1. One-Piece, Cast-Brass Type: With polished, chrome-plated finish and setscrew fastener.
2. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with chrome-plated finish and spring-clip fasteners.
3. Split-Casting Brass Type: With polished, chrome-plated finish and with concealed hinge and setscrew.

B. Floor Plates:

1. One-Piece Floor Plates: Cast-iron flange with holes for fasteners.
2. Split-Casting Floor Plates: Cast brass with concealed hinge.

PART 3 - EXECUTION

3.1. VALVE APPLICATIONS

A. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install drip-pan elbow on safety-valve outlet and pipe without valves to the outdoors; pipe drain to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements.

B. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

3.2. HYDRONIC SPECIALTIES INSTALLATION

A. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Install manual vents at heat-transfer coils and elsewhere as required for air venting.

B. Install piping from equipment to expansion tank with a 2 percent upward slope toward tank.

C. Install tangential air separator in pump suction. Install blowdown piping with gate or full-port ball valve; extend full size to nearest floor drain.

D. When indicated, install expansion tanks above the air separator. Install tank fitting in tank bottom and charge tank. Use manual vent for initial fill to establish proper water level in tank.

1. Install tank fittings that are shipped loose.

2. Support tank from floor or structure above with sufficient strength to carry weight of tank, piping connections, fittings, plus tank full of water. Do not overload building components and structural members.

E. When indicated, install expansion tanks on the floor. Vent and purge air from hydronic system and ensure that tank is properly charged with air to suit system Project requirements.

3.3. BUFFER TANKS

A. Install indoor vertical buffer tanks on concrete housekeeping pads and support horizontal tanks from structural members above. Install outdoor buffer tanks on concrete pad with crushed stone base. Design supports based on tank weight full or water. Do not overload building components and structural members.

B. Install each piping connection with shutoff isolation valve and P/T wells for thermostat and temperature sensor.

C. Install automatic air vent at top of tank tapping and pipe vent to floor drain.

D. Install drain piping with ball valve and pipe to floor drain.

E. Insulate tanks. Comply with Section 230719.

3.4. ESCUTCHEONS AND FLOOR PLATES 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. New Piping: Install one-piece cast-brass type for new piping installations. Install deep-pattern type where piping sleeve protrudes from the floor or wall.

2. Existing Piping: Install split-casting brass type for existing piping installations.

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. New Piping: One-piece, floor-plate type.
2. Existing Piping: Split-casting, floor-plate type.

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

END OF SECTION

SECTION 23 21 19 – HYDRONIC PIPING VALVES

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes general duty valves for HVAC piping systems such as ball, butterfly, check, and globe valves and associated accessories.

1.2. SUBMITTALS

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

1.3. 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 B31.1 for power piping valves.
3. ASME B31.9 for building services piping valves.

1.4. 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 globe valves closed to prevent rattling.
4. Set ball and plug valves open to minimize exposure of functional surfaces.
5. Set butterfly valves closed or slightly open.
6. Block check valves in either closed or open position.

B. Use the following precautions during storage:

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

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

PART 2 - PRODUCTS

2.1. GENERAL REQUIREMENTS

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

1. Apollo Valves / Conbraco
2. Bray
3. Crane Company / Crane Fluid Systems
4. DeZurik
5. Metso / Jamesbury and Neles
6. Milwaulkee Valve / Hammond Valve
7. NIBCO
8. Powell Valves

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

C. Combination valves that combine multiple valve and specialty functions will not be accepted unless specifically noted.

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

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

F. Valve Actuator Types:

1. Gear Actuator: For quarter-turn valves 6-inches NPS and larger.
2. Handwheel: For valves other than quarter-turn types.
3. Hand Lever: For quarter-turn valves 4-inches NPS and smaller except plug valves.
4. Wrench: For plug valves with square heads. Furnish Owner with 1 wrench for every 5 plug valves, for each size square plug-valve head.
5. Valves shall be equipped with means to lock them closed in compliance with OSHA Lock-out / Tag-out procedure.

G. Valves in Insulated Piping: Provide valves with 2-inch stem extensions for piping temperatures 180 deg F and lower and 4-inch for above 180 deg F.

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.

H. Valve-End Connections:

1. Flanged: With flanges according to ASME B16.1 for iron valves.

2. Threaded: With threads according to ASME B1.20.1.

3. Socket Welded: 2-inch NPS and smaller piping.

4. Solder Joint: With sockets according to ASME B16.18. Use solder with melting point below 840 deg F, except for ball valves where the melting point shall be below 421 deg F.

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

2.2. BALL VALVES

A. Ball Valves, 2-inches NPS and smaller: Two-piece, full-port, quarter-turn, forged brass ball valves with stainless steel trim, PTFE or TFE seats, adjustable stem packing and anti-blowout stem, rated for 600 psig CWP (cold working pressure). Valves shall comply with MSS SP-110. Valves shall have threaded ends.

2.3. BUTTERFLY VALVES

A. Butterfly Valves, 2 1/2-inches NPS and larger: Iron single-flange, cast-iron or ductile-iron butterfly valves with carbon steel disc, stainless steel stem, EPDM seat, rated for 150 psig CWP (cold working pressure). Valve body shall be lug type suitable for bi-directional dead-end service at rated pressure without the use of a downstream flange. Valves shall comply with MSS SP-67, Type I. Valves shall have flanged ends.

2.4. CHECK VALVES

A. Lift Check Valves, 2-inches NPS and smaller: Bronze lift check valves for vertical flow with bronze disc and Class 125 rated for 200 psig CWP (cold working pressure). Valves shall comply with MSS SP-80. Valves shall have threaded ends.

B. Center-Guided Check Valves, 2 1/2-inches NPS and larger: Center-guided spring-loaded globe type check valves with ductile iron body, EPDM or NBR seat, and Class 150 rated for 250 psig CWP (cold working pressure). Valves shall comply with MSS SP-125. Valves shall have flanged ends.

2.5. GLOBE VALVES

A. Globe Valves, 2-inches NPS and smaller: Bronze body with integral seat and union-ring bonnet globe valves with bronze trim, PTFE or TFE seats and asbestos-free packing, Class 150 rated for 300 psig CWP (cold working pressure). Hand-wheels shall be malleable or ductile iron. Valves shall comply with MSS SP-80. Valves shall have threaded ends.

B. Globe Valves, 2 1/2-inches NPS and larger: Iron body and bolted-bonnet globe valves with bronze trim, PTFE or TFE seats and asbestos-free packing, Class 125 rated for 200 psig CWP (cold working pressure). Hand-wheels shall be malleable or ductile iron. Valves shall comply with MSS SP-85. Valves shall have flanged ends.

2.6. MANUAL CALIBRATED BALANCING VALVES

A. Manual Calibrated Balancing Valves:

1. Manufacturers:

    a. Armstrong CBV Series

    b. Bell & Gossett Circuit Setter Plus Series

    c. Griswold QuickSet Series

    d. TACO Accu-Flo Series.

    e. Victaulic TA 78 Series

2. Flow Verification: Provide a differential pressure versus flow calibration charts for use by the Engineer and TAB sub-contractor.

B. Manual Calibrated Balancing Valves, 2-inches NPS and smaller: Manual balancing valve with bronze or copper-alloy body; calibrated ball or globe type orifice or venturi for flow control; brass or stainless ball; PTFE seat; two pressure gage connections with integral seals for portable differential pressure meter; drain tapping; and rated for 125 psig CWP (cold working pressure). Valve shall have hand lever shall have memory stop and integral pointer and calibrated scale to register the degree of valve opening. Valves shall have threaded ends.

C. Manual Calibrated Balancing Valves, 2 1/2-inches NPS and larger: Manual balancing valve with cast or ductile-iron body; calibrated ball or globe type orifice or venturi for flow control; brass or stainless ball; PTFE seat; two pressure gage connections with integral seals for portable differential pressure meter; drain tapping; and rated for 125 psig CWP (cold working pressure). Valve shall have hand lever shall have memory stop and integral pointer and calibrated scale to register the degree of valve opening. Valves shall have flanged ends.

2.7. AUTOMATIC BALANCING VALVES

A. Automatic Balancing Valves: Valves shall maintain constant flow within 5 percent, plus or minus, over system pressure fluctuations.

1. Flow Verification: Provide electronic differential pressure meter that can read differential pressure including flowmeter, probes, hoses, flow charts and carrying case.

2. Cartridge Exchange: For up to 1 year from acceptance of the final TAB Report, up to 10% of cartridges in the project may be replaced as needed for any reason as determined by the Engineer.

B. Automatic Balancing Valves, 2-inches NPS and smaller: Combination automatic balancing valve and isolation valve with Y-pattern brass body; removable stainless steel flow cartridge; stainless steel spring; EPDM O-ring; two pressure and temperature ports; and rated for 175 psig CWP (cold working pressure). Isolation valve shall be quarter-turn ball valve with brass or stainless steel ball. Flow cartridge shall be stamped with flow rate.

1. Manufacturers:

    a. Flow Design (FDI) AutoFlow AC Series

    b. Griswold Isolator R Series

    c. Nexus Valve UltraMatic UM Series

d. Victaulic 76 Series

C. Automatic Balancing Valves, 2 1/2-inches NPS and larger: Automatic balancing valve with wafer-style ductile-iron body; stainless steel flow cartridge; stainless steel spring; EPDM cartridge seal; two pressure and temperature ports; and rated for 200 psig CWP (cold working pressure).

1. Manufacturers:

a. Flow Design (FDI) WS Series

b. Griswold Wafer Series

c. Nexus Valve UltraMatic UMW Series.

d. Victaulic 76G Series

2.8. CONTROL VALVES

A. Comply with the requirements of Section 239010.

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. Install valves in branch lines to isolate sections of the piping system.

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

D. Install valves in horizontal piping with stem at or above center of pipe. Valves with stems below center of piping are not acceptable.

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

F. Valves shall be equipped with stem extensions for all applications where the piping will be insulated.

G. Install shut-off duty valves at each branch connection to supply mains and at supply connection to each piece of equipment.

H. Install check valves at each pump discharge and elsewhere as required to control flow direction.

I. Install check valves for proper direction of flow and as follows:

1. Swing Check Valves: In horizontal position with hinge pin level.

2. Wafer-Type Check Valves: In horizontal or vertical position, between flanges.

3. Lift Check Valves: With stem upright and plumb.

J. Install balancing valves in the return pipe of each heating or cooling terminal.

K. Install control valves in locations indicated in details and as needed to perform the sequence of operations.

L. Install pressure / temperature ports as indicated in the details and on the inlet and discharge side of each balancing and control valve.

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. Hydronic piping systems shall use the following valve types unless otherwise indicated on the drawings or in other Division 23 sections:

1. Shutoff: Ball or butterfly.

2. Shutoff on heat exchangers served from centralized distribution systems on the source side and the first isolation valve, supply and return, on the building load side: High performance butterfly valves

3. Throttling: Globe, ball or butterfly.

4. Pump Discharge Check Valves: Lift check valves for 2-inches NPS and smaller. Non-slam, center-guided, globe type check valves for 2 1/2-inches NPS and larger.

5. Balancing:

a. Two-Way Modulating, Pressure Dependent Control Valves: Automatic.

b. Two-Way Two-Position Pressure Dependent Control Valves: Automatic.

c. Three-Way Modulating Pressure Dependent Control Valves: Automatic.

d. Constant Speed Pumps: Manual-calibrated with balanced flow set point.

e. Boilers and Chillers: Automatic.

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.

END OF SECTION

SECTION 23 21 23 – HYDRONIC PUMPS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes HVAC hydronic system pumps.

1.2. SUBMITTALS

A. Product Submittals: For each type of pump. Include certified performance curves and rated capacities, operating characteristics, furnished specialties, final impeller dimensions, and accessories for each type of product indicated. Indicate pump's operating point on curves.

1. Proposed pump data shall include all potential motor sizes, impeller sizes, total head, flow rates and efficiency curves. Pump curves showing only the proposed selection point data is not acceptable.

B. Close-Out Submittals:

1. Operation and Maintenance Data: For pumps to include in emergency, operation, and maintenance manuals.

1.3. QUALITY ASSURANCE

A. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

B. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

1.4. EXTRA MATERIALS

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. Mechanical Seals: One mechanical seal(s) for each pump.

PART 2 - PRODUCTS

2.1. MANUFACTURERS

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

1. Centrifugal Pumps:

a. Armstrong Pumps

b. Bell & Gossett

c. TACO

2. Cooling Coil Condensate Pumps:

a. Armstrong Pumps/Hartell Pumps

b. Bell & Gossett

c. Little Giant Pump/Franklin Electric

B. Motors: Comply with requirements of Section 230513.

2.2. CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

A. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically.

B. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gage-tappings at inlet and outlet, replaceable bronze wear rings and flanged connections.

2. Impeller: Stainless steel Type 304; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For constant-speed pumps, trim impeller to match specified performance.

3. Pump Shaft: Stainless steel or carbon steel.

4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless-steel spring, and ethylene propylene terpolymer (EPT) or ethylene propylene rubber (EPR) bellows and gasket. Include water slinger on shaft between motor and seal.

5. Pump Bearings: Permanently lubricated ball bearings.

C. Motor: Single speed and rigidly mounted to pump casing.

2.3. SEPARATELY COUPLED, VERTICALLY MOUNTED, IN-LINE CENTRIFUGAL PUMPS

A. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted vertically.

B. Pump Construction:

1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, replaceable bronze wear rings and flanged connections.

2. Impeller: Stainless steel Type 304; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For pumps not frequency-drive controlled, trim impeller to match specified performance.

3. Pump Shaft: Stainless steel or carbon steel.

4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless-steel spring, and ethylene propylene terpolymer (EPT) or ethylene propylene rubber (EPR) bellows and gasket. Include water slinger on shaft between motor and seal.

5. Seal: Packing seal consisting of stuffing box with a minimum of four rings of graphite-impregnated braided yarn with bronze lantern ring between center two graphite rings, and bronze packing gland.

6. Pump Bearings: Permanently lubricated ball bearings.

C. Shaft Coupling: Axially split spacer coupling.

D. Motor: Single speed and rigidly mounted to pump casing with lifting eyebolt and supporting lugs in motor enclosure.

2.4. AUTOMATIC CONDENSATE PUMP UNITS

A. Description: Packaged units with corrosion-resistant pump, plastic tank with cover, and automatic controls. Include factory or field-installed check valve and electrical connection.

B. Capacity: Refer to drawings for performance requirements. Where not identified, the pump capacities shall be based on the cooling coil's total cooling capacities:

1. 1.5-tons or less: 0.50 GPH (0.01 GPM) at 5-foot of head lift.

2. 3-tons or less: 1.00 GPH (0.02 GPM) at 5-foot of head lift.

3. Greater than 3 tons: 0.33 GPH (0.0055 GPM) per 1 total cooling ton at 5-foot of head lift.

C. Electrical Connection: 120V, hard-wired connection with 12-inch maximum flexible conduit. Cord and plug connection is not acceptable.

2.5. PUMP SPECIALTY FITTINGS

A. Suction Diffuser:

1. Angle pattern.

2. 175-psig pressure rating, ductile-iron body and end cap, pump-inlet fitting.

3. Strainer:

a. Closed-Loop Systems: Bronze fine-straining startup screen and stainless-steel medium-straining permanent screen strainers.

4. Bronze or stainless-steel straightening vanes.

5. Drain plug.

6. Factory-fabricated support.

B. Triple-Duty Valve:

1. Angle or straight pattern.

2. 175-psig pressure rating, ductile-iron body, pump-discharge fitting.

3. Drain plug and bronze-fitted shutoff, balancing, and check valve features.

4. Brass gage ports with integral check valve and orifice for flow measurement.

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine equipment foundations and anchor-bolt locations for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.

C. Examine foundations and inertia bases for suitable conditions where pumps are to be installed.

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

3.2. PUMP INSTALLATION

A. Comply with HI 1.4 and HI 2.4.

B. Install pumps to provide access for periodic maintenance including removing motors, impellers, couplings, and accessories.

C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.

D. Automatic Condensate Pump Units: Install units for collecting condensate and extend to open drain.

E. Equipment Mounting:

1. Install base-mounted pumps 15 hp and smaller on cast-in-place concrete equipment bases.

2. Install in-line pumps with continuous-thread hanger rods and spring hangers with vertical-limit stop of size required to support weight of in-line pumps.

3.3. ALIGNMENT

A. Engage a factory-authorized service representative to perform alignment service.

B. Comply with requirements in Hydronics Institute (HI) standards for alignment of pump and motor shaft. Add shims to the motor feet and bolt motor to base frame. Do not use grout between motor feet and base frame.

C. Comply with pump and coupling manufacturers' written instructions.

D. Use a laser-alignment tool and provide a report documenting the results of the final alignment within acceptable tolerances. Verify the alignments are within the manufacturer's recommended tolerances or the following maximums, whichever is stricter:

1. Short Couplings:

a. Pumps at 1200 rpm: 3.0 mils (0.0030-inches) offset and 0.6 mils/inch angularity.

b. Pumps at 1800 rpm: 2.5 mils (0.0025-inches) offset and 0.4 mils/inch angularity.

c. Pumps at 3600 rpm: 1.5 mils (0.0015-inches) offset and 0.3 mils/inch angularity.

2. Spacer Couplings:

a. Pumps at 1200 rpm: 1.1 mils/inch angularity.

b. Pumps at 1800 rpm: 0.8 mils/inch angularity.

c. Pumps at 3600 rpm: 0.4 mils/inch angularity.

E. After alignment is correct, tighten foundation bolts evenly but not too firmly. Completely fill baseplate with non-shrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

3.4. CONNECTIONS

A. Where installing piping adjacent to pump, allow space for service and maintenance.

B. Connect piping to pumps. Install valves that are same size as piping connected to pumps.

C. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles.

D. Install check, shutoff and throttling valves on discharge side of pumps not equipped with a variable speed drive. Install check and shutoff valves on discharge side of pumps equipped with a variable speed drive.

E. Install suction diffuser and shutoff valve on suction side of base-mounted pumps and Y-type strainer and shutoff valve on suction side of in-line pumps.

F. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.

G. Install pressure gages on pump suction and discharge or at integral pressure-gage tapping or install single gage with multiple-input selector valve. A single differential pressure gauge is not acceptable.

H. Install check valve and gate or ball valve on each condensate pump unit discharge.

I. Ground equipment according to Division 26 specifications.

J. Connect wiring according to Division 26 specifications.

3.5. 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.

2. Check piping connections for tightness.

3. Clean strainers on suction piping.

4. Perform the following startup checks for each pump before starting:

    a. Verify bearing lubrication.

    b. Verify that pump is free to rotate by hand and that pump for handling hot liquid is free to rotate with pump hot and cold. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.

    c. Verify that pump is rotating in the correct direction.

5. Prime pump by opening suction valves and closing drains and prepare pump for operation.

6. Start motor.

7. Open discharge valve slowly.

3.6. DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps.

END OF SECTION

SECTION 23 25 00 – HVAC WATER TREATMENT

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes components of closed-circuit hydronic water treatment systems.

1.2. SUBMITTALS

A. Qualification Submittals:

1. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

B. Product Submittals: For each type of product indicated include rated capacities, operating characteristics, and furnished specialties and accessories.

1. Shop Drawings: Pretreatment and chemical showing tanks, maintenance space required, and piping connections to HVAC systems.

2. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.

C. Close-Out Submittals:

1. Operation and Maintenance Data: Include emergency, operation, and maintenance manuals for each system component.

1.3. QUALITY ASSURANCE

A. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

B. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

1.4. WATER TREATMENT PROVIDER

A. Water treatment service and chemicals shall be performed by the Contractor with an Owner approved vendor.

PART 2 - PRODUCTS

2.1. PERFORMANCE REQUIREMENTS

A. Water quality for HVAC systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or to the environment.

B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.

C. Closed-Circuit Hydronic System Water Qualities: Maintain the following range of values:

1. pH: 9.0 to 10.5.
2. "P" Alkalinity: 100 to 500 ppm.
3. Boron: 100 to 200 ppm.
4. Chemical Oxygen Demand: 100 ppm maximum (not applicable to glycol solutions).
5. Soluble Copper: 0.20 ppm maximum.
6. Total Suspended Solids (TSS): 10 ppm maximum.
7. Ammonia: 20 ppm maximum.
8. Free Caustic Alkalinity: 20 ppm maximum.
9. Microbiological Limits:
    a. Total Aerobic Plate Count: 1,000 organisms/mL maximum.
    b. Total Anaerobic Plate Count: 100 organisms/mL maximum.
    c. Nitrate Reducers: 100 organisms/mL maximum.
    d. Sulfate Reducers: 0 organisms/mL maximum.
    e. Iron Bacteria: 0 organisms/mL maximum.

2.2. MANUAL CHEMICAL-FEED EQUIPMENT

A. Bypass Feeders: 5-gallon steel bypass feeder rated for 125 psig minimum working pressure with corrosion-resistant exterior coating; minimum 3 1/2-inch fill opening in the top; and 3/4-inch NPS bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel. Manufactured by Amtrol, Armstrong, Bell & Gossett or TACO.

2.3. CHEMICAL TREATMENT TEST EQUIPMENT

A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing pH, TSS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers.

B. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.

1. Two station rack for closed-circuit systems.

2.4. CHEMICALS

A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment and that can attain water quality specified.

PART 3 - EXECUTION

3.1. WATER ANALYSIS

A. Perform an analysis of supply water to determine quality of water available at Project site.

3.2. INSTALLATION

A. Install chemical application equipment on concrete bases level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.

B. Install water-testing equipment on wall near water-chemical-application equipment.

C. Bypass Feeders: Install in closed hydronic systems.

1. Install bypass feeder in a bypass circuit around circulating pumps unless otherwise indicated on Drawings.
2. Install water meter in makeup-water supply.
3. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.
4. Install ball isolation valves on inlet, outlet, and drain below feeder inlet.
5. Install a swing check on inlet after the isolation valve.

3.3. CONNECTIONS

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where installing piping adjacent to equipment, allow space for service and maintenance.

C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings.

D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet.

E. See Section 221319 for backflow preventers required in makeup-water connections to potable-water systems.

F. Confirm applicable electrical requirements in electrical Sections for connecting electrical equipment.

G. Ground equipment and connect wiring according to Division 26.

3.4. FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:

1. Inspect field-assembled components and equipment installation.

2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.

3. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of HVAC system's startup procedures.

4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.

5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.

6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.

7. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.

8. Repair leaks and defects with new materials and retest piping until no leaks exist.

C. Equipment will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

E. At four-week intervals following Owner Acceptance, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis advising Owner of changes necessary to adhere to "Performance Requirements" Article.

F. Comply with ASTM D 3370 and with the following standards:

1. Silica: ASTM D 859.

2. Acidity and Alkalinity: ASTM D 1067.

3. Iron: ASTM D 1068.

4. Water Hardness: ASTM D 1126.

3.5. MAINTENANCE SERVICE

A. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion, scale formation, and biological growth for all hydronic systems and equipment. Services and chemicals shall be provided for a period of one year from date of Owner Acceptance and shall include the following:

1. Initial water analysis and HVAC water-treatment recommendations.
2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
3. Periodic field service and consultation.
4. Customer report charts and log sheets.
5. Laboratory technical analysis.
6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

3.6. DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

END OF SECTION

SECTION 23 31 13 – METAL DUCTS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes single and double-wall round, oval and rectangular metal duct and fittings and associated sealants, gaskets, hangers and supports.

1.2. PERFORMANCE REQUIREMENTS

A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated in "Duct Schedule" Article.

B. Delegated Outdoor Duct Support Design: Duct support construction shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and be suitable for outdoor conditions including attachment details and support and curb heights for snow and rain.

1. Comply with Section 230548 for wind and seismic restraints.

C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE-62.1.

1.3. SUBMITTALS

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

1. Shop Drawings: For all new ductwork and accessories.

a. Factory and shop-fabricated ducts and fittings.

b. Reinforcement and spacing.

c. Seam and joint construction.

d. Details for penetrations through fire-rated and other partitions.

e. Hangers and supports, including methods for duct and building attachment and vibration isolation.

f. Sheet metal thicknesses.

B. Construction Submittals:

1. Leakage Test Report: Documentation of work performed for compliance with ASHRAE 90.1, Section 6.4.4.2.2 - "Duct Leakage Tests."

C. Close-Out Submittals:

1. As-Built Documents: Provide revised construction drawings to indicate the installed conditions as part of the complete HVAC As-Built Drawing set. The as-built drawings shall be professionally drafted and noted so they are easily read by others.

1.4. DEFINITIONS

A. System Operating Pressure: Duct system operating pressure is equal to the scheduled external static pressure, unless otherwise noted.

1. Duct downstream of air terminal units, between terminal unit discharge and diffuser inlet, the operating pressure may be reduced to 1-inch w.g., unless otherwise noted.

PART 2 - PRODUCTS

2.1. 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 Steel Sheets: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation:

a. G60: Non-hazardous systems such as supply, return, ventilation, relief and general building exhaust duct installed indoors.

b. G90: All duct installed outdoors.

2. Finishes for Surfaces Exposed-to-View: Painted.

C. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304, cold rolled, annealed, sheet. Exposed surface finish shall be No.4.

D. Aluminum Sheets: Comply with ASTM B209 Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.

E. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

F. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36-inches or less; 3/8-inch minimum diameter for lengths longer than 36-inches.

2.2. DUCT CONSTRUCTION

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class with the following exceptions:

1. Minimum Sheet Metal Thickness:

    a. Non-hazardous ducted systems including supply, return, ventilation, relief and general building exhaust air.

        1) Galvanized Sheet Steel: 0.028-inches (24-gage).

        2) Stainless Sheet Steel: 0.025-inches (24-gage).

        3) Aluminum Sheet Metal: 0.020-inches (24-gage).

2. Minimum Construction Standards: Refer to the Table below for minimum construction standards in addition to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible".

METAL DUCT MINIMUM CONSTRUCTION STANDARDS

DUCT SYSTEMS	MAXIMUM OPERATING PRESSURE (+/- IN WG)	SMACNA DUCT PRESSURE CLASS. (+/- IN WG)	SMACNA SEAL CLASS (A, B or C)	SMACNA LEAKAGE CLASS (C)	LONGITUDINAL SEAM TYPES	TRANSVERSE JOINT TYPES	FITTING CONSTRUCTION
RECTANGULAR DUCT	1.0	1	A	8	L-1	T-1, 3, 6, 17, 19, 22, 24 (Note #3)	6, 7 and 8
	1.5	2	A	8	L-1	T-1, 3, 6, 17, 19, 22, 24 (Note #3)	6 and 7
	2.5	3	A	8	L-1	T-17, 19, 22 and 24 (Note #3)	6 and 7
	3.0	4	A	4	L-1	T-22 (Note #3)	6 and 7
	5.0	6	A	4	L-1	T-22 (Note #3)	6 and 7
	8.0	10	A	4	L-1	T-22 (Note #3)	6 and 7
ROUND DUCT WITH LONGITUDINAL SEAMS	1.0	1	A	8	RL-4, 5, 6A, 6B, 7 and 8	RT-1, 2, 3, 4, 5 and 6 (Note #4)	10 and 14
	1.5	2	A	8	RL-4 and 5	RT-1 and 2 (Note #4)	10, 11, 13 and 14
	2.5	3	A	4	RL-4 and 5	RT-2 (Note #4)	10, 11, 13 and 14
	3.0	4	A	2	RL-4 and 5 (Poss. Press. Only)	RT-2 (Note #4)	10, 11, 13 and 14
	5.0	6	A	2	RL-4 and 5 (Poss. Press. Only)	RT-2 (Note #4)	10, 11, 13 and 14
	8.0	10	A	2	RL-4 and 5 (Poss. Press. Only)	RT-2 (Note #4)	10, 11, 13 and 14
ROUND DUCT WITH SPIRAL SEAMS	1.0	1	A	8	RL-1 (Spiral)	RT-1 and 2 (Note #4)	10, 11, 13 and 14
	1.5	2	A	8	RL-1 (Spiral)	RT-2 (Note #4)	10, 11, 13 and 14
	2.5	3	A	4	RL-1 (Spiral)	RT-2 (Note #4)	10, 11, 13 and 14
	3.0	4	A	2	RL-1 (Spiral)	RT-2 (Note #4)	10, 11, 13 and 14
	5.0	6	A	2	RL-1 (Spiral)	RT-2 (Note #4)	10, 11, 13 and 14
	8.0	10	A	2	RL-1 (Spiral)	RT-2 (Note #4)	10, 11, 13 and 14
FLAT OVAL DUCT WITH LONGITUDINAL SEAMS	1.0	1	A	8	RL-4 and 5	RT-2 (Note #5)	12, 13 and 14
	1.5	2	A	8	RL-4 and 5	RT-2 (Note #5)	12, 13 and 14
	2.5	3	A	4	RL-4 and 5	RT-2 (Note #5)	12, 13 and 14
	3.0	4	A	2	RL-4 and 5 (Poss. Press. Only)	RT-2 (Note #5)	12, 13 and 14
	5.0	6	A	2	RL-4 and 5 (Poss. Press. Only)	RT-2 (Note #5)	12, 13 and 14
	8.0	10	A	2	RL-4 and 5 (Poss. Press. Only)	RT-2 (Note #5)	12, 13 and 14
FLAT OVAL DUCT WITH SPIRAL SEAMS	1.0	1	A	8	RL-1 (Spiral)	RT-1 and 2 (Note #5)	12, 13 and 14
	1.5	2	A	8	RL-1 (Spiral)	RT-2 (Note #5)	12, 13 and 14
	2.5	3	A	4	RL-1 (Spiral)	RT-2 (Note #5)	12, 13 and 14
	3.0	4	A	2	RL-1 (Spiral)	RT-2 (Note #5)	12, 13 and 14
	5.0	6	A	2	RL-1 (Spiral)	RT-2 (Note #5)	12, 13 and 14
	8.0	10	A	2	RL-1 (Spiral)	RT-2 (Note #5)	12, 13 and 14

NOTES:

1. REFER TO SMACNA 'HVAC DUCT CONSTRUCTION STANDARD - METAL AND FLEXIBLE' (2005) FOR SEAM, JOINT AND FITTING TYPES.
2. REFER TO SMACNA 'HVAC AIR DUCT LEAKAGE TEST MANUAL' (2012) FOR PRESSURE, SEAL AND LEAKAGE CLASSES.
3. FACTORY-FABRICATED SLIDE-ON CONNECTORS ALSO MAY BE USED, DUCTMATE TYPE 35 OR 25, OR EQUAL BY WARD OR NEXUS.
4. FACTORY-FABRICATED SLIDE-ON CONNECTORS ALSO MAY BE USED, DUCTMATE SPIRAL-MATE, OR EQUAL BY WARD OR NEXUS.
5. FACTORY-FABRICATED SLIDE-ON CONNECTORS ALSO MAY BE USED, DUCTMATE OVAL-MATE, OR EQUAL BY WARD OR NEXUS.
6. OPERATING PRESSURES ARE BASED ON MAXIMUM DESIGN PRESSURES, ALSO REPRESENTED AS EXTERNAL STATIC PRESSURES (ESP).
7. USE MINIMUM SMACNA DUCT PRESSURE CLASSIFICATION OF 1 IN WG. DO NOT USE 1/2 INCH CLASSIFICATION.

B. Double-Wall Duct:

1. Double-wall rectangular ducts and fittings shall be fabricated in an off-site dedicated ductwork fabrication shop. Field fabricated double-wall duct will not be accepted.

   a. Interstitial Insulation: Comply with Section 230713.

   b. Minimum Thermal Resistance: Comply with Section 230713.

c. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.

d. Inner Duct: Minimum 24-gage solid galvanized sheet steel.

2. Double-wall round and flat-oval ducts and fittings shall be fabricated in an off-site dedicated ductwork fabrication shop. Field fabricated double-wall duct will not be accepted.

   a. Interstitial Insulation: Comply with Section 230713

   b. Minimum Thermal Resistance: Comply with Section 230713

   c. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.

   d. Coat insulation with antimicrobial coating.

   e. Inner Duct: Minimum 24-gage solid galvanized sheet steel.

C. Intermediate Reinforcement: Match duct material.

D. 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. Radius Type RE-3 with minimum 1.0 radius-to-diameter ratio and two vanes.

   c. Mitered Type RE-2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

      1) Fabricate elbows with single thickness blades with 2-inch inside radius for ducts with dimensions up to 18x18 and double thickness blades for dimensions 18x18 and larger.

      2) Turning vanes may be deleted when duct dimensions are less than 12x12.

2. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."

   a. Elbows shall be solid welded gored type constructed in accordance with Fig. 3-6 and Table 3-1 of SMACNA HVAC Duct Construction Standards. Mitered elbows may only be used where indicated on the Drawings. When used, mitered elbows shall always be supplied with single thickness turning vanes.

   b. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible”.

      1) Velocity up to 1500 fpm: 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.

2) Velocity 1500 fpm or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.

c. Round Elbows:

1) Diameter 8-inches and Smaller: Stamped or pleated.

a) Adjustable elbows with lock-form joints are also acceptable.

2) Diameter 10-inches and Larger: Welded gore-type.

a) 90-degree elbows shall have minimum 5 gores.

b) 45-degree elbows shall have minimum 3 gores.

E. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."

a. Rectangular Main to Rectangular Branch: 45-degree entry.

b. Rectangular Main to Round Branch:

1) Velocity up to 1500 fpm: Conical.

2) Velocity greater than 1500 fpm: 45-degree lateral.

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. Round and Flat Oval Main to Round Branch:

1) Velocity up to 1000 fpm: 90-degree tee.

2) Velocity up to 2000 fpm: Conical.

3) Velocity greater than 2000 fpm: 45-degree lateral.

3. Construct tees, bends, and elbows with minimum radius 1-1/2 times centerline duct width. Where not possible and where rectangular elbows are used, provide airfoil turning vanes. Where acoustical lining is indicated, furnish turning vanes of perforated metal with glass fiber insulation.

4. Increase duct sizes gradually, not exceeding 15 degrees divergence wherever possible; maximum 30 degrees divergence upstream of equipment and 45 degrees convergence downstream.

5. Fabricate continuously welded round and oval duct fittings two gages heavier than duct gages indicated in SMACNA Standard. Minimum 4-inch cemented slip joint, brazed or electric welded. Prime coat welded joints.

6. Provide standard 45-degree lateral wye takeoffs. When space does not allow 45-degree lateral wye takeoff, use 90-degree conical tee connections. Straight 90-degree round take-offs are allowed off rectangular ducts for single diffuser taps only.

7. Divided or diverging flow fittings shall be constructed as separate fittings. Tap collars welded into spiral duct sections are not acceptable.

F. General Cleanliness Requirements: Comply with SMACNA's "Duct Cleanliness for New Construction Guidelines".

1. Minimum Duct Cleanliness Level: C ("Advanced Level")

a. Internal surfaces shall be wiped clean after fabrication prior to sealing for shipment.

b. Self-adhesive labels may be affixed to only the outside surfaces of the duct.

2.3. TRAVERSE DUCT CONNECTION SYSTEM

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

1. Ductmate.

2. Ward.

3. Nexus.

B. Product Description: SMACNA "F" rated or SMACNA "J" rated rigidity class connection, interlocking angle and duct edge connection system with sealant, gasket, cleats, and corner clips.

C. Duct connectors shall be equal to Ductmate 35 or 25 Systems, slide-on type. The 35 System joint shall be the equivalent of a SMACNA "J" connection. The 25 System joint shall be the equivalent of the SMACNA "F" connection. Duct connectors shall be tested by an independent recognized testing laboratory.

D. Duct connectors shall consist of roll formed angle frames with integral sealant, corner pieces with nuts and bolts, metal cleats and gasketing. (Metal cleats only, PVC cleats not acceptable, with the exception of breakaway joints at fire damper sleeves.)

E. Gasketing shall be equal to Ductmate Type 440 synthetic polymer (Butyl) based gasket/sealing tape or approved equal.

F. Connectors shall be selected for the system duct construction specified. Select in accordance with SMACNA HVAC Duct Construction Standards, Metal and Flexible and the manufacturers published criteria for positive and negative applications. The manufacturer shall assist in the selection of all duct connectors. Select methods of construction and gages as required to accommodate prefabricated duct connectors.

G. Angle flange connectors shall be fastened in each corner and 12-inches o/c minimum thereafter unless the MFR requires more stringent fastening. The type/style of fastening must be submitted for approval prior to ductwork fabrication.

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. Two-Part Tape Sealing System:

1. Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.
2. Tape Width: 4 inches.
3. Sealant: Modified styrene acrylic.
4. Water resistant.
5. Mold and mildew resistant.
6. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
7. Service: Indoor and outdoor.
8. Service Temperature: Minus 40 to plus 200 deg F.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.
10. 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).

C. Water-Based Joint and Seam Sealant:

1. Application Method: Brush on.
2. Solids Content: Minimum 65 percent.
3. Shore A Hardness: Minimum 20.
4. Water resistant.
5. Mold and mildew resistant.
6. VOC: Maximum 75 g/L (less water).
7. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
8. Service: Indoor or outdoor.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

D. Flanged Joint Sealant: Comply with ASTM C 920.

1. General: Single-component, acid-curing, silicone, elastomeric.
    a. Type: S.
    b. Grade: NS.
    c. Class: 25.
    d. Use: O.

2. 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).

E. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

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, "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.

2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.

3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

PART 3 - EXECUTION

3.1. DUCT SCHEDULE

A. General Building Air Systems: Applies to general building supply, return, exhaust, ventilation and relief air duct. Refer to Part 2, Metal Duct Minimum Construction Standards chart for construction standards of standard supply, transfer, return and exhaust duct. Refer to this Duct Schedule section for special applications.

1. Indoor Duct:

a. Concealed or Exposed to View in Mechanical Rooms: Single-wall galvanized sheet steel. Round and oval duct shall have longitudinal or spiral seams.

b. Exposed to View in Occupied Spaces: Double-wall galvanized sheet steel. Round and oval duct shall have spiral seams.

2. Outdoor Duct:

a. Insulated Systems: Double-wall Type 304 stainless steel outer shell and galvanized steel inner duct.

b. Uninsulated Systems: Single-wall Type 304 stainless steel.

3. Special Applications:

a. Shower / Bathing Areas: Duct up to 10-feet from each air inlet shall be constructed with Type 304 stainless steel or aluminum.

B. Air Plenums: Applies to air plenums for general building ventilation and relief air systems.

1. Construction: Plenums shall be constructed with materials matching connected duct construction.

2. Access Doors: Refer to Section 233300 for access door requirements.

3.2. 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. Duct Dimensions: Dimensions in the construction documents indicate as follows:

1. Rectangular Duct: Nominal inside width and height of the duct.

2. Round Duct: Nominal inside diameter of the duct.

3. Oval Duct: Nominal inside width and depth diameter (of the round sides connecting the flat portions) of the duct.

4. Double-Wall Duct: For double-wall duct, the inside is defined as the inner-duct.

C. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

D. Install ducts according to SMACNA’s “Duct Cleanliness for New Construction Guidelines”.

1. Store duct, fittings and accessories on pallets in a clean and dry location.

2. All sections of duct, fittings and accessories shall be sealed for shipping and storage. They may be sealed at all openings with polyethylene film, shrink-wrapped, bagged or equivalent. Exposed openings shall remain sealed until temporary filtration is in place.

3. Temporary filter media shall be installed on both return and exhaust ducts/inlets if system is operated for conditioning prior to occupancy.

4. Internal surfaces shall be wiped clean as each is installed to prevent construction dust and debris from accumulating.

E. Install round and flat-oval ducts in maximum practical lengths.

F. Install ducts with fewest possible joints.

G. Install factory or shop fabricated fittings for changes in direction, size, and shape and for branch connections.

H. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

I. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

J. Install ducts with a clearance of 1-inch plus allowance for insulation thickness.

K. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

L. 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.

M. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements of the specifications for fire and smoke dampers.

N. 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."

3.3. DUCT WELDING

A. Duct welding materials and methods shall be in accordance with AWS Standard D9.1-90 Sheet Metal Welding Code.

B. Electrode material and flux shall be compatible with the sheet metal material being welded.

C. Re-coat any galvanizing damaged as a result of welding with a zinc-rich paint, such as Porter Zinc-Lock 351 – Gray.

D. Stainless Steel Ductwork Welding:

1. Welding Process: Welding process shall be inert gas shielded tungsten arc process. Electric current for welding shall be direct current, straight polarity (electrode negative and work positive).

2. Shielding and Purging: Shielding and purging gas shall be welding grade helium, argon or a mixture of both.

3. Electrodes: Electrodes shall be 2-percent thoriated tungsten conforming to AWS classification and complying with AWS A5.4, AWS A5.9, and AWS A5.12.

4. Grinding and Polishing: The inside and outside of welds shall have burrs and rough spots removed with a tungsten carbide file or grinder. Final polishing shall be with the proper grit (free of iron) abrasive grinder with flexible flap, drum or roll wheel.

3.4. INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.

D. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

E. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.5. HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Where practical, install concrete inserts before placing concrete.
2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.
4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.
5. Do not use powder-actuated concrete fasteners for seismic restraints.

C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at maximum intervals of 10 feet.

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

G. Install outdoor duct, supports and building attachments to comply with Section 230548 wind and seismic restraint requirements. Coordinate attachments with building structure and roof.

3.6. CONNECTIONS

A. Make connections to equipment with flexible connectors.

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.7. PAINTING

A. Paint interior of all metal duct that is visible through registers and grilles and that does not have duct liner.

B. Paint exterior of all galvanized metal duct that is exposed-to-view. Do not paint stainless steel duct unless otherwise directed.

1. Exception: Do not paint duct in mechanical rooms, mezzanines or penthouses.

C. Painting Duct:

1. Clean duct of dirt, grease and lubricants with a non-hydrocarbon “green” cleaner.

2. Prime duct with 2 coats of water-based white acrylic primer paint designed for use with galvanized steel.

3. Finish duct with 2 coats of latex paint.

a. Exterior Duct Surfaces: Color and finish shall be chosen by the owner/ architect.

b. Interior Duct Surfaces: Flat black.

D. Apply paint and primer at the recommended spreading rate and film thickness as recommended by the paint manufacturer.

E. Apply paint and primer within the environmental conditions recommended by the paint manufacturer but not less than 55F; not more than 90F; and not more than 70% RH.

F. Mill phosphatized or bonderized ”paint grip” steel is not acceptable. Galvannealed sheet metal using a continuous hot-dipping method is an acceptable alternative.

3.8. FIELD QUALITY CONTROL

A. Engineer to inspect all ductwork at operating pressure prior to insulation for leakage. All leakage shall be repaired.

B. Perform tests and inspections.

C. Leakage Pressure Tests:

1. Test 100% of supply, return, exhaust, relief and ventilation duct at pressures equal to their maximum static pressure classifications. Do not over-pressurize systems above their maximum designed operating pressure.

a. Low pressure duct (2-inches w.g. or less) listed below shall be tested for leakage unless, in the judgement of the Engineer, it is not required. The Engineer has the option to make this judgement based on a visual inspection of the quality of sealant application. Poor workmanship will result in leakage testing of all duct.

1) Return air duct for return plenum systems under negative pressure and less than 30 ft. total length of duct.

2) Return air duct from the intake of fan coil units and blower coil units under negative pressure and less than 30 ft. total length of duct.

3) Exhaust air duct under negative pressure and less than 30 ft total length of duct.

4) Ventilation air duct under negative pressure and less than 30 ft. total length of duct.

5) Supply air duct from the discharge of terminal units, fan coil units and blower coil units under positive pressure and less than 30 ft. total length of duct.

2. Test duct leakage per 2013 ASHRAE Fundamentals Handbook Chapter 21and 2016 ASHRAE HVAC Systems and Equipment Handbook Chapter 19 with an average leakage rate for each duct system as specified in Table 3 for the leakage class specified in Part 3 of this section.

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. Provide 10-day notice for testing.

6. Testing performed prior to the installation of duct accessories, such as dampers and access doors, is not valid. Alterations of the systems due to incomplete or non-conforming work made after testing will void previous test results and require new testing at no additional cost to the owner or engineer. Verify related work is complete before starting.

D. 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.

E. Duct system will be considered defective if it does not pass tests and inspections.

F. Prepare test and inspection reports.

END OF SECTION

SECTION 23 33 00 – METAL DUCT ACCESSORIES

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes air duct accessories including relief, volume, control and life-safety dampers; flexible ducts; flange and flexible connectors; turning vanes; duct silencers; duct-mounted access doors; and duct hardware.

1.2. SUBMITTALS

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

1. For duct silencers, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.

B. Close-Out Submittals:

C. Life-Safety Damper Inspection Reports: Document testing and results for all life-safety dampers including installation and operation inspection, engineer’s inspections and AHJ’s inspections.

1. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

1.3. EXTRA MATERIALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fusible Links: Furnish quantity equal to 10 percent of amount installed but no less than 10 total.

PART 2 - PRODUCTS

2.1. ASSEMBLY DESCRIPTION

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

C. Provide dampers constructed with materials matching the duct system.

1. Exception: Use Type 304 stainless steel in galvanized duct subject to moist airstreams such as humidifiers, locker room exhaust, pool rooms, steam autoclaves, etc.

2.2. MATERIALS

A. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G60.

2. Exposed-Surface Finish: Mill phosphatized.

B. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304, and having a No. 2 finish for concealed ducts and No. 4 finish for exposed ducts.

C. Aluminum Sheets: Comply with ASTM B 209, Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.

D. Extruded Aluminum: Comply with ASTM B 221, Alloy 6063, Temper T6.

E. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

F. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36-inches or less; 3/8-inch minimum diameter for lengths longer than 36-inches.

2.3. STATIC PRESSURE GAGES

A. Dial Gages: 3-1/2 inch diameter dial in metal case, diaphragm actuated, black figures on white background, front calibration adjustment, 2-percent of full scale accuracy.

B. Accessories: Static pressure tips with compression fittings for bulkhead mounting, 1/4-inch diameter tubing. Provide 3-way vent valves.

2.4. GRAVITY BALANCED BACKDRAFT AND PRESSURE RELIEF DAMPERS

A. Description: Gravity-balanced dampers for backdraft or pressure relief. Dampers shall have adjustable tension return spring; steel ball bearings; counter-weights and spring-assist kits for vertical flow applications; and bird screens. Unless otherwise indicated, dampers shall be rated for 2000 fpm maximum air velocity and 2-inches w.g. maximum system pressure.

1. Frame: Hat-shaped with welded corners or mechanically attached and mounting flange, constructed of one of the following to match the duct system material type for each: 12-gauge thick, galvanized sheet steel; 0.063-inch thick extruded aluminum; or 0.05-inch thick stainless steel.

2. Blades: Parallel-action, multiple single-piece blades, center pivoted, maximum 6-inch width, 0.025-inch thick, roll-formed aluminum with mechanically-locked neoprene blade seals and 0.20-inch diameter stainless steel blade axles.

2.5. BAROMETRIC RELIEF DAMPERS

A. Description: Barometric relief dampers for pressure relief. Dampers shall have return spring or adjustable tension counter-weight; stainless steel bearings; and bird screens. Unless otherwise indicated, dampers shall be rated for 2000 fpm maximum air velocity and 2-inches w.g. maximum system pressure.

1. Frame: Hat-shaped with welded corners or mechanically attached and mounting flange, constructed of one of the following to match the duct system material type for each: 16-

gauge thick, galvanized sheet steel; 0.093-inch thick extruded aluminum; or 18-gauge stainless steel.

2. Blades: Parallel-action, multiple single-piece blades, center pivoted, maximum 6-inch width, 0.050-inch thick, roll-formed aluminum with mechanically-locked neoprene blade seals and 0.20-inch diameter stainless steel blade axles.

2.6. MANUAL VOLUME DAMPERS

A. Standard Rectangular, Steel, Manual Volume Dampers: Standard leakage rating suitable for horizontal or vertical volume control applications with molded synthetic bearings. Unless otherwise indicated, dampers shall be rated for 2000 fpm maximum air velocity and 2.5-inches w.g. maximum system pressure. Provide dampers equivalent to Ruskin MD35.

1. Frame: Hat-shaped with welded corners, constructed of 16-gauge thick, galvanized sheet steel, with flanges for wall attachments or flangeless for in duct installations.

2. Blades: Opposed-blade action, multiple single-piece blades, center-pivot, maximum 8-inch width, 16-gauge thick galvanized steel, galvanized steel blade axles and exposed linkage. Provide 2-inch handle extension wherever duct system will be insulated.

B. Standard Round, Steel, Manual Volume Dampers: Standard leakage rating suitable for horizontal or vertical volume control applications with molded synthetic bearings. Unless otherwise indicated, dampers shall be rated for 1500 fpm maximum air velocity and 2-inches w.g. maximum system pressure. Provide dampers equivalent to Ruskin MDRS25

1. Frame: Constructed of 20-gauge thick galvanized sheet steel, flangeless for in duct installations.

2. Blades: Single-blade, center-pivot, 20-gauge thick galvanized sheet steel, 0.375-inch diameter galvanized steel blade axle and 90-deg quadrant handle. Provide 2-inch handle extension wherever duct system will be insulated.

C. Damper Hardware: Zinc-plated, die-cast core with hand quadrant dial and handle made of 3/32-inch thick zinc-plated steel, and hexagon locking nut. Include elevated platform for insulated duct mounting.

1. Handle operation shall be painted orange.

2.7. CONTROL DAMPERS

A. Standard Low-Pressure Rectangular, Steel, Control Dampers: Standard leakage rated damper suitable for horizontal or vertical volume control applications with synthetic or stainless steel bearings. Dampers shall be rated for 2,000 fpm maximum air velocity, 2.5-inches w.g. maximum system pressure and maximum leakage of 10 cfm/sqft. at 1.0-inches pressure. Provide dampers equivalent to Ruskin CD35.

1. Frame: Hat-shaped with welded corners, constructed of 16-gauge thick, galvanized sheet steel, with flanges for wall attachments or flangeless for in duct installations.

2. Blades: Opposed-blade action, multiple single-piece blades, center-pivot, maximum 6-inch width, 16-gauge thick galvanized steel, galvanized steel blade axles and exposed linkage. Provide 2-inch handle extension wherever duct system will be insulated.

3. Applications:

a. Operating Pressure: Up to 2.0-inches w.g.

b. Operating velocity: Up to 1,500 fpm.

c. Throttling: Opposed-blade type.

d. Two-Position (Open/Closed): Parallel type.

B. Standard Medium-Pressure Rectangular, Steel, Control Dampers: AMCA Class 2 leakage damper suitable for horizontal or vertical volume control applications with oil-impregnated stainless steel bearings. Dampers shall be rated for 3,000 fpm maximum air velocity and 5.0-inches w.g. maximum system pressure. Provide dampers equivalent to Ruskin CD36.

1. Frame: Hat-shaped with welded corners, constructed of 16-gauge thick, galvanized sheet steel, with flanges for wall attachments or flangeless for in duct installations.

2. Blades: Opposed-blade action, multiple single-piece blades, center-pivot, maximum 6-inch width, 16-gauge thick galvanized steel, galvanized steel blade axles and exposed linkage. Provide 2-inch handle extension wherever duct system will be insulated.

3. Applications:

a. Operating Pressure: Up to 4.0-inches w.g.

b. Operating velocity: Up to 2,500 fpm.

c. Throttling: Opposed-blade type.

d. Two-Position (Open/Closed): Parallel type.

C. High-Performance Medium-Pressure Rectangular, Steel, Control Dampers: AMCA Class 1A leakage damper suitable for horizontal or vertical volume control applications with oil-impregnated self-lubricating stainless steel bearings. Dampers shall be rated for 6,000 fpm maximum air velocity and 13.0-inches w.g. maximum system pressure. Provide dampers equivalent to Ruskin CD60.

1. Frame: Hat-shaped with welded corners, constructed of 16-gauge thick, galvanized sheet steel, with flanges for wall attachments or flangeless for in duct installations.

2. Blades: Opposed-blade action, multiple single-piece blades, center-pivot, maximum 8-inch width, 14-gauge thick galvanized steel, galvanized steel blade axles and exposed linkage with synthetic elastomer on the blade edges and stainless steel compression type seals. Provide 2-inch handle extension wherever duct system will be insulated.

3. Applications:

a. Operating Pressure: Up to 12.0-inches w.g.

b. Operating velocity: Up to 5,000 fpm.

c. Throttling: Opposed-blade type.

d. Two-Position (Open/Closed): Parallel type.

D. Standard Low-Pressure Round, Steel, Control Dampers: Standard rating suitable for horizontal or vertical volume control applications with molded synthetic bearings. Unless otherwise indicated, dampers shall be rated for 1,500 fpm maximum air velocity and 2.0-inches w.g. maximum system pressure. Provide dampers equivalent to Ruskin MDRS25.

1. Frame: Constructed of 20-gauge thick galvanized sheet steel, either with flanges on both sides or internal duct mounting.

2. Blades: Single-blade action, 20 gauge-thick steel, center-pivot, closed cell rubber edge seals and galvanized steel blade axles.

3. Applications:

   a. Operating Pressure: Up to 1.0-inches w.g.

   b. Operating velocity: Up to 1,000 fpm.

E. Medium-Pressure Round and Oval, Steel, Control Dampers: AMCA Class 2 damper suitable for horizontal or vertical volume control applications with stainless steel bearings. Unless otherwise indicated, dampers shall be rated for 4,000 fpm maximum air velocity and 10.0-inches w.g. maximum system pressure. Provide dampers equivalent to Ruskin CDR25 (round) / CDO25 (oval).

1. Frame: Constructed of 14-gauge thick galvanized sheet steel, either with flanges on both sides or internal duct mounting.

2. Blades: Single-blade action, 12 gauge-thick steel, center-pivot, closed cell rubber edge seals and galvanized steel blade axles.

3. Applications:

   a. Operating Pressure: Up to 8.0-inches w.g.

   b. Operating velocity: Up to 3,200 fpm.

2.8. LIFE-SAFETY DAMPERS

A. General Requirements:

1. Temperature Activation Rating: Fusible links and/or heat sensors shall be rated for 165 deg F in general air duct systems (up to 120 deg F) and rated for 212 deg F in high temperature duct systems (greater than 120 deg F) such as smoke control.

2. Frame Style: Rectangular life-safety dampers shall have Type B curtain-style blades outside the air stream except for tight locations where otherwise noted or pre-approved by the Engineer.

3. Minimum Dimensions: Damper height or width dimension shall be minimum 8-inches to allow a minimum 12-inch by 6-inch access door and adequate space to test and maintain damper, regardless of duct dimensions. Refer to ‘Duct-Mounted Access Doors’ in this section for more information about sizing.

4. Sidewall Grilles: Dampers installed behind sidewall grilles shall be fully serviceable through the grille.

B. Fire Dampers: 1-1/2 and 3-hour UL 555 and FM rated and labeled dynamic fire dampers suitable for horizontal or vertical applications with 4-inch w.g. closing rating static pressure class and minimum 2000 fpm rated velocity.

1. Horizontal dampers shall include stainless steel closure spring.
2. Frame: Factory-fabricated with roll-formed 20-gauge thick galvanized steel and mitered and interlocking corners.
3. Mounting Sleeve: Factory installed galvanized sheet steel, minimum thickness to suit application.
4. Blades: Roll-formed, interlocking, 20-gauge thick, galvanized sheet steel. In place of interlocking blades, use full-length, 20-gauge thick, galvanized-steel blade connectors.

2.9. TURNING VANES

A. Turning Vanes for Metal Ducts: Factory-fabricated, double-wall, curved airfoil-shaped blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting. Comply with details in SMACNA “HVAC Duct Construction Standards – Metal and Flexible”

2.10. DUCT-MOUNTED ACCESS DOORS

A. General: Factory-fabricated access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 7-2, "Duct Access Doors and Panels," and 7-3, "Access Doors - Round Duct."

   1. Doors: Factory-fabricated access doors shall be air-tight suitable for associated duct pressure and leakage classification. All doors shall be rigid and close fitting and include sealing gaskets and quick locking devices. Door construction materials shall match metal duct type, galvanized steel, stainless steel or aluminum.

      a. Access doors must be installed prior to duct pressure and leakage testing. If the Engineer determines the access doors cannot meet the requirements of the testing, they shall be replaced with a higher quality door at the contractor’s expense.

      b. Access panels with sheet metal screw fasteners are not acceptable.

   2. Frames: Galvanized sheet steel, with bend-over tabs and foam or neoprene gaskets. Security chain to restrain door to frame.

   3. Hinges and Latches:

      a. Doors up to 12-inches Square: Secure with sash locks.

      b. Doors up to 18-inches Square: Provide two hinges and two sash locks.

      c. Doors up to 24 x 48 Inches: Three hinges and two compression latches with outside and inside handles.

      d. Larger door sizes: Provide an additional hinge.

   4. Vision Panels: 12-inch square wired-glass vision panels in all access doors larger than 6 sqft. and where noted, including:

      a. Plenum Access Doors.

B. Standard Duct-Mounted Access Doors: Doors in uninsulated duct shall be single-wall. Doors in insulated duct shall be double-wall with 1-inch of mineral fiber or foam insulation fill.

1. Rectangular Duct-Mounted Access Doors: Rectangular and square access doors for rectangular and flat oval duct.

   a. Life-Safety Damper Access: Doors installed to provide access to life-safety dampers shall be minimum 12-inches square.

      1) Duct without a 14-inch or larger dimension shall transition to a size with at least one 14-inch dimension to allow for 12-inch square access door.

         a) Exemptions: Sidewall grilles and ceiling radiation dampers.

      2) Ducts with a dimension from 14 to 24-inches shall have square access doors 2-inches less than largest duct dimension.

      3) Ducts with a dimension of 26-inches or larger shall have 24-inch by 24-inch duct access doors.

   b. Equipment and Sensor Access: 12 x 6-inch rectangular access doors shall be used in 8-inch largest dimension ducts; 12 x 8-inch rectangular doors in up to 12-inch ducts; 12-inch square doors in up to 18-inch ducts; 18-inch square doors in up to 24-inch ducts; and 24-inch square doors in 26-inch and larger ducts.

2. Oval and Round Duct-Mounted Access Doors: Oval access doors for round and oval ducts. Equivalent to Ruskin ADR Series.

   a. Door Sizes: 8-inch by 4-inch access doors shall be used in 4 and 6-inch diameter round ducts; 10-inch by 6-inch doors in 6 to 12-inch ducts; and 16-inch by 12-inch doors in 14-inch and larger ducts.

      1) Life-Safety Damper Access: Transition round and oval duct to rectangular duct matching life-safety damper dimensions. Install access doors in accordance with Rectangular Duct-Mounted Access Doors paragraph above.

C. Plenum-Mounted Access Doors: Open outward for positive-pressure ducts and inward for negative-pressure ducts. Full height plenums shall have 72-inch tall x 30-inch wide door with vision panel and mounted between 4 and 12-inches above the floor unless otherwise indicated.

2.11. DUCT TEST HOLES

A. Permanent Test Holes: Factory-fabricated, air-tight, flanged fittings with screw cap. Furnish extended neck fittings to clear insulation.

2.12. 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 3-1/2 inches wide attached to two strips of 2-3/4-inch wide, 0.028-inch thick, galvanized sheet steel or 0.032-inch thick aluminum sheets. Provide metal compatible with connected ducts.

D. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene with a minimum weight of 26 oz/sqyd; tensile strength of 480 lbf/inch in the wrap and 360 lbf/inch in the filling; and a service temperature range of (-) 40 deg F to 200 deg F.

E. Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber resistant to UV rays and ozone with a minimum weight of 24 oz/sqyd; tensile strength of 530 lbf/inch in the wrap and 440 lbf/inch in the filling; and a service temperature range of (-) 50 deg F to 250 deg F.

F. Thrust Limits: Combination coil spring and elastomeric insert with spring and insert in compression, and with a load stop. Include rod and angle-iron brackets for attaching to fan discharge and duct. They shall be factory-fabricated for HVAC applications up to 10-inches w.g. of pressure.

G. Grounding Straps: Flexible braided copper grounding strips, flat or round, providing an equivalent ampacity of a #6 AWG conductor.

2.13. FLEXIBLE DUCTS

A. General: Flexible duct shall comply with UL 181, Class 1 and have flame spread rating of less than 25 and smoke developed rating of less than 50.

B. Non-Insulated, Flexible Duct: Aluminum laminate and polyester film with latex adhesive supported by helically wound, spring-steel wire. Duct shall have 10-inch w.g. positive and 1-inch w.g. negative pressure ratings; maximum air velocity of 4000 fpm; and temperature rating of (-) 20 deg F to 210 deg F.

C. Insulated, Flexible Duct: Double-ply polyester film supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene vapor-barrier film. Duct shall have 10-inch w.g. positive and 1-inch w.g. negative pressure ratings; maximum air velocity of 4000 fpm; and temperature rating of (-) 10 deg F to 160 deg F. Insulation value shall meet or exceed R-value of connected duct insulation.

D. Flexible Duct Connectors: Stainless steel bands with cadium-plated hex screws to tighten band with a worm gear action sized to suit duct size.

2.14. 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.

B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

PART 3 - EXECUTION

3.1. INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Install static pressure gages to measure across filters and filter banks, (inlet to outlet). On multiple banks, provide manifold and single gage.

1. Provide instruments with scale ranges selected according to service with largest appropriate scale. Filter gauges shall be 0 to 2-inch scale.

D. Install control dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.

E. Whether or not indicated on plans, install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel. Damper construction materials shall match duct system materials.

1. Volume damper handle positions shall match volume damper positions. If the damper is closed, the handle should be perpendicular to the direction of airflow. If the damper is open, the handle should be parallel to the direction of airflow.

F. Set dampers to fully open position before testing, adjusting, and balancing.

G. Install test holes at fan inlets and outlets and elsewhere as indicated.

H. Install life-safety dampers according to UL listing and coordinate their location and adjacent installations to ensure they are fully accessible for maintenance and testing.

I. Access Doors: Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:

1. On both sides of duct coils.
2. Upstream from duct filters.
3. At outdoor-air intakes and mixed-air plenums.
4. At drain pans and seals.
5. Downstream from control dampers, backdraft dampers, and equipment.
6. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
7. Control devices requiring inspection or cleaning.

8. Elsewhere as indicated.

J. Install access doors with swing against duct static pressure.

K. Label access doors according to Section 230553 to indicate the purpose of access door.

L. Install temporary duct test holes as required for testing and balancing purposes. Cut or drill ducts. Cap with neat patches, neoprene plugs, threaded plugs, or threaded or twist-on metal caps.

M. Install flexible connectors to connect ducts to equipment. Install flexible grounding strip(s) from equipment to duct.

N. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

O. Connect diffusers to ducts with <u>up to 6-foot maximum lengths of flexible duct</u> clamped or strapped in place, unless otherwise indicated.

P. Connect flexible ducts to metal ducts with adhesive plus sheet metal screws and tape.

Q. Install duct test holes where required for testing and balancing purposes.

R. Install thrust limits at centerline of thrust, symmetrical on both sides of equipment. Attach thrust limits at centerline of thrust and adjust to a maximum of 1/4-inch movement during start and stop of fans.

3.2. CONTROL DAMPERS

A. Control Dampers for Air Handling Equipment:

1. Outside Air (OA) Dampers: Provide damper types noted in the air handling unit sections and on the drawings. Dampers sized for 2,000 FPM face velocity at full flow and 100 FPM at 5-percent flow.

    a. Opposed-blade type.

    b. Parallel-blade type. Orient blades to direct air flow away from coils and toward outside air flow to promote mixing.

2. Relief Air (RelA) / Exhaust Air (EA) Dampers:

    a. Fan: Opposed-blade type sized for 2,000 FPM face velocity at full flow.

    b. Barometric: Parallel-blade type sized for 1,000 FPM face velocity at full flow.

3. Return Air (RA) Dampers: Parallel-blade type sized for 1,500 FPM face velocity at full flow. Orient blades to direct air flow away from coils and toward outside air flow to promote mixing.

3.3. 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, smoke, and combination fire and smoke 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.

5. Operate remote damper operators to verify full range of movement of operator and damper.

6. Life-Safety Damper Testing: Dampers shall be 100% tested and verified to be open and operational through their full range of movement. Damper testing shall be performed by contractor with minimum 5-years of experience in testing life-safety dampers. Within 2 weeks of written certification that all dampers are correct, Engineer shall inspect dampers prior to AHJ inspection.

   a. Test Procedures:

      1) Fire dampers with fusible links shall be tested by removing the fusible link. Observe that damper closes completely.

      2) Fire dampers with firestats shall be tested with a heat gun. Observe that damper closes completely.

      3) If any dampers do not close completely, correct installation and retest.

      4) After verification of damper closing, verify that damper reopens to normal position without blockage of air flow. Reset fusible links and firestats. Close access door.

   b. Test Report:

      1) Provide written report to Engineer and signed by the responsible Contractor representatives.

      2) Report shall list each fire and smoke damper with test results for each damper including time, date, and name of test technician for each test.

      3) Report shall include a table showing each damper with a unique identification for each damper. Report shall include a notation of whether damper is in supply, return, exhaust or other type of duct.

      4) Report shall include drawings showing the location of each damper on the floor plans.

3.4. DEMONSTRATION

A. Demonstrate re-setting of fire dampers for Owner and Engineer.

B. Provide Owner training in compliance with Section 230200.

END OF SECTION

SECTION 23 34 00 – HVAC FANS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes centrifugal roof ventilators.

1.2. PERFORMANCE REQUIREMENTS

A. Operating Limits: Classify according to AMCA 99.

1.3. SUBMITTALS

A. Product Submittals: For each type of product indicated include rated capacities, operating characteristics, and furnished specialties and accessories. The product data shall also include the following: certified fan performance curves with system operating conditions indicated; certified fan sound-power ratings; motor ratings and electrical characteristics, plus motor and electrical accessories; material thickness and finishes; dampers, including housings, linkages, and operators; roof curbs; and fan speed controllers.

B. Close-Out Submittals:

1. Operation and Maintenance Data: For power ventilators to include in emergency, operation, and maintenance manuals.

1.4. QUALITY ASSURANCE

A. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

B. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

1.5. EXTRA MATERIALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Belts: Two set(s) for each belt-driven unit.

PART 2 - PRODUCTS

2.1. GENERAL REQUIREMENTS

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

1. Greenheck Fan Corp.
2. Loren Cook Company
3. PennBarry
4. Twin City Fan and Blower

B. Description: Factory fabricated, assembled, tested, and finished, belt-driven or direct-driven (as scheduled) fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly and support structure with factory installed and wired service disconnect switch. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations.

C. AMCA Compliance: Comply with AMCA performance requirements and bear the AMCA-Certified Ratings Seal. Classify operating limits according to AMCA 99.

1. Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.
2. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210/ASHRAE 51, "Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating."

D. Shafts: Fan shafts shall be statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with adjustable alignment and belt tensioning. Shafts shall be turned, ground, and polished hot-rolled steel with keyway and finished with an anti-corrosive coating. They shall be designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

E. Pre-lubricated and Sealed Shaft Bearings: Self-aligning, pillow-block type bearings rated for L10 at 100,000 hours.

1. Extend grease fitting to accessible location outside of unit.

F. Belt Drives: Factory mounted, with adjustable alignment and belt tensioning, and with 1.5 service factor based on fan motor.

1. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
2. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
3. Belts: Oil resistant, non-sparking, and non-static V-belts; in matched sets for multiple-belt drives.
4. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.

5. Motor Mount: Adjustable for belt tensioning.

G. Direct Drives: Factory-mounted with 1.2 service factor based on fan motor.

H. Motors: Comply with requirements of Section 230513.

I. Speed Controller: Where indicated, provide solid-state, factory-mounted, manual speed controller on 115V or 230V single-phase, direct-drive fans for air flow balancing.

J. Variable Frequency Controllers: Refer to Section 230514.

1. Variable frequency drives shall not be installed outdoors without supplemental cooling.

K. Motor Starters and Disconnects: Refer to Section 230511.

1. Disconnect Switch: Factory wired and mounted non-fusible type with thermal-overload protection mounted to the fan housing, unless otherwise indicated. Wiring shall be enclosed in aluminum conduit.

L. Dampers: Motor-operated, parallel blade aluminum dampers mounted in the curb base shall open when the fan starts and close when it stops. Refer to Section 233300.

1. Where indicated, provide counter-balanced backdraft dampers in lieu of motor-operated type.

M. Roof Curbs: Factory-fabricated welded-seam self-flashing roof curb to match fan and roof-slope, constructed of galvanized sheet metal with 1 1/2-inch pressure-treated wood nailer, water-tight gasket, 1 1/2-inches of rigid fiberglass insulation, damper tray, and finished with primer and powder baked white enamel.

1. Wind and Seismic Restraints: Metal brackets compatible with the curb and casing, painted to match exhaust fan, used to anchor unit to the curb, and designed for loads at project site. Comply with requirements in Section 230548.

2. Curb Height: 14-inches with a minimum of 12-inches above the finished roof surface.

2.2. CENTRIFUGAL ROOFTOP FANS

A. General Description: Rooftop fan with removable spun-aluminum dome top and outlet baffle; square one-piece aluminum base with venture inlet cone; fan wheel with aluminum hub and wheel with backward-inclined blades; and belt or direct-drive as scheduled. Outlet shall have removable 1/2-inch aluminum mesh birdscreen. The drive shall be equipped with an automatic belt tensioner.

B. Rooftop Dome-Type Upblast Centrifugal Fans: Fan housing shall have spun-aluminum discharge baffle to direct discharge air upward with rain drains. Greenheck CUE/CUBE Series, Loren Cook ACR Series, PennBarry Fumex FX Series or Twin City BCRU/DCRU Series.

1. Application: General building exhaust systems.

2. Sidewall Applications: Provide sidewall mounting accessories.

PART 3 - EXECUTION

3.1. GENERAL INSTALLATION

A. Install power ventilators level and plumb.

B. Equipment Mounting:

1. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548.

C. Secure roof-mounted fans to roof curbs with cadmium-plated hardware.

D. Ceiling Units: Suspend units from structure; use steel wire or metal straps.

E. Support suspended units from structure using threaded steel rods and spring hangers with vertical-limit stops having a static deflection of 1 inch. Vibration-control devices are specified in Section 230548.

F. Install units with clearances for service and maintenance.

G. Label units according to requirements specified in Section 230553.

3.2. CONNECTIONS

A. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Section 233300.

B. Install ducts adjacent to fans to allow service and maintenance.

C. Ground equipment according to Division 26.

D. Connect wiring according to Division 26.

3.3. FIELD QUALITY CONTROL

A. Perform the following tests and inspections:

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
3. Verify that cleaning and adjusting are complete.
4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
5. Adjust belt tension.
6. Adjust damper linkages for proper damper operation.
7. Verify lubrication for bearings and other moving parts.
8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.

9. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.

10. Shut unit down and reconnect automatic temperature-control operators.

11. Remove and replace malfunctioning units and retest as specified above.

B. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Prepare test and inspection reports.

3.4. ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension.

C. Comply with requirements in Section 230593 for testing, adjusting, and balancing procedures.

D. Replace fan and motor pulleys as required to achieve design airflow. Coordinate with the TAB Contractor.

E. Lubricate bearings.

END OF SECTION

SECTION 23 37 13 – DIFFUSERS, REGISTERS AND GRILLES

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes duct, ceiling, wall and floor-mounted air inlets and outlets.

1.2. SUBMITTALS

A. Product Submittals: For each type of 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.

2. Diffuser, Register, and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

1.3. QUALITY ASSURANCE

A. Comply with NFPA 90A and NFPA 90B.

PART 2 - PRODUCTS

2.1. METAL DIFFUSERS, GRILLES & REGISTERS

A. Manufacturers: Provide products that comply with the construction documents and are manufactured by one of the following, unless otherwise noted in this section:

1. Krueger

2. Metalaire

3. Nailor Industries

4. Price

5. Titus

B. General Requirements: Devices shall be specifically designed for variable air volume flows. Insulate backpan. Border type shall match each installation. Ceiling, wall, sill or duct-mounting as indicated. Face and neck dimensions as indicated. Inside of each backpan and duct plenum shall be painted flat black so that there is no visible metal from the face.

C. Materials: Provide devices constructed of the following materials unless otherwise indicated.

1. Material: Steel, aluminum, or stainless steel as noted.

2. Finish: Baked enamel, anodized aluminum, or primed-for-paint as noted.

a. Color: White, unless otherwise noted.

D. Volume Dampers: Provide manual volume damper at each air inlet or outlet branch duct tap, whether shown on the drawings or not, regardless of the diffuser, grille or register having an integral damper unless specifically noted otherwise. Dampers shall comply with Section 233300.

2.2. SUPPLY AIR DIFFUSERS

A. Round Louvered Face Ceiling Diffuser: Four cone, louvered, full-face diffuser with adjustable horizontal-to-vertical 360-degree discharge pattern, equalizing grid and foam rubber gasket. Where indicated, provide opposed-blade neck mounted manual volume damper that is operable from the diffuser face. Titus TMRA series or equal.

B. Square Louvered Face Ceiling Diffuser: Three cone, louvered, full-face diffuser with adjustable vane 360-degree discharge pattern, equalizing grid and foam rubber gasket. Where indicated, provide opposed-blade neck mounted manual volume damper that is operable from the diffuser face. Titus TMSA series or equal.

C. Standard Blade Grille: Double-deflection, adjustable, standard blade grille with front horizontal and rear vertical blades spaced at 3/4-inch. The blades shall be at 0-degree or 45-degree deflection as indicated. Where indicated, provide opposed-blade neck mounted manual volume damper that is operable from the diffuser face. Titus 300 series or equal.

2.3. RETURN, EXHAUST AND TRANSFER AIR GRILLES AND REGISTERS

A. Square Perforated Face Ceiling Grille: Perforated flush face grille with equalizing grid, foam rubber gasket and pre-formed insulation blanket. Provide backpan with duct connection collar where connected to ductwork. Where indicated, provide opposed-blade neck mounted manual volume damper that is operable from the diffuser face. Titus PAR series or equal.

B. Standard Blade Grille: Single-deflection, fixed, standard blade grille with front horizontal and rear vertical blades spaced at 3/4-inch. The blades shall be at 0-degree or 35-degree deflection as indicated. Where indicated, provide opposed-blade neck mounted manual volume damper that is operable from the grille face. Titus 350 series or equal.

C. Filter Grille: Fixed deflection filter return grille with front horizontal blades spaced at 3/4-inch with foam rubber gasket. The blades shall be at 35 to 45-degree deflection as indicated. Provide 2-inch thick filter frame and hinged grille face with quarter-turn fasteners. Titus 350 series or equal.

2.4. SOURCE QUALITY CONTROL

A. Verification of Performance: Rate diffusers, registers, and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine areas where 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 practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

C. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

D. Diffusers, registers and grilles shall be supported at two (2) opposite ends to the building steel/concrete frame or floor decking. Supports shall be provided with the same type of wire as used to support lay-in ceiling track.

E. Insulate diffusers, grilles and registers to prevent condensation. Coordinate insulation with Section 230713.

1. Insulate the plenum box for all linear and slot supply air diffusers and grilles.

2. Insulate the backpan of all surface-mounted supply air diffusers and grilles.

3. Insulate the backpan of all surface-mounted return / exhaust air grilles and registers where the connected ductwork penetrates the building’s thermal and vapor barrier or is routed through unconditioned spaces such as attics, mechanical rooms, basements and crawl spaces.

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

SECTION 23 51 00 – BREECHINGS, CHIMNEYS AND STACKS

PART 1 - GENERAL

1.1. SUMMARY

A. This section includes breechings, chimneys and stacks for fuel burning devices.

1.2. SUBMITTALS

A. Qualification Submittals:

1. Welding certificates.

B. Product Submittals: For each breeching, chimney and stack specified in this section.

1. Shop Drawings: For vents, breechings, chimneys, and stacks. Include plans, elevations, sections, details, and attachments to other work.

a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, methods of field assembly, components, hangers and seismic restraints, and location and size of each field connection.

2. Warranty: Special warranties specified in this Section.

1.3. QUALITY ASSURANCE

A. Source Limitations: Obtain listed system components through one source from a single manufacturer.

B. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code--Steel," for hangers and supports and AWS D9.1/D9.1M, "Sheet Metal Welding Code," for shop and field welding of joints and seams in vents, breechings, and stacks.

C. Certified Sizing Calculations: Manufacturer shall certify venting system sizing calculations.

PART 2 - PRODUCTS

2.1. LISTED SPECIAL GAS VENTS, STAINLESS STEEL

A. Description: Double-wall metal vents tested according to UL 1738 and rated for 480 deg F continuously, with positive or negative flue pressure complying with NFPA 211.

B. Construction: ASTM A 959, Type 29-4C stainless steel inner shell and aluminized steel outer jacket separated by at least 1/2-inch airspace.

C. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners;

fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.

1. Termination: Round chimney top designed to exclude minimum 98 percent of rainfall.

2.2. GUYING AND BRACING MATERIALS

A. Cable: Three galvanized, stranded wires of the following thickness:

1. For ID Sizes 4 to 15 Inches: 5/16 inch.
2. For ID Sizes 18 to 24 Inches: 3/8 inch.
3. For ID Sizes 27 to 30 Inches: 7/16 inch.
4. For ID Sizes 33 to 36 Inches: 1/2 inch.
5. For ID Sizes 39 to 48 Inches: 9/16 inch.
6. For ID Sizes 51 to 60 Inches: 5/8 inch.

B. Pipe: Two galvanized steel, 1-1/4-inches NPS.

C. Angle Iron: Two galvanized steel, 2 by 2 by 0.25 inch.

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of work.

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

3.2. APPLICATION

A. Listed Special Gas Vent: Condensing gas appliances.

3.3. INSTALLATION OF LISTED VENTS AND CHIMNEYS

A. Locate to comply with minimum clearances from combustibles and minimum termination heights according to product listing or NFPA 211, whichever is most stringent.

B. Seal between sections of positive-pressure vents according to manufacturer's written installation instructions, using sealants recommended by manufacturer.

C. Support vents at intervals recommended by manufacturer to support weight of vents and all accessories, without exceeding appliance loading.

D. For appliances that are 83 percent or more efficient, slope breechings down in direction of appliance, with condensate drain connection at lowest point piped to nearest drain.

E. Lap joints in direction of flow.

F. Connect base section to foundation using anchor lugs of size and number recommended by manufacturer.

G. Join sections with acid-resistant joint cement to provide continuous joint and smooth interior finish.

H. Erect stacks plumb to finished tolerance of no more than 1 inch out of plumb from top to bottom.

3.4. CLEANING

A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

B. Clean breechings internally, during and after installation, to remove dust and debris. Clean external surfaces to remove welding slag and mill film. Grind welds smooth and apply touchup finish to match factory or shop finish.

C. Provide temporary closures at ends of breechings, chimneys, and stacks that are not completed or connected to equipment.

END OF SECTION

SECTION 23 52 16 – CONDENSING BOILERS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes gas-fired condensing boilers, trim, and accessories for generating heating hot water.

1.2. SUBMITTALS

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

1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for boilers.

2. Include rated capacities, operating characteristics, and furnished specialties and accessories.

3. Shop Drawings: For boilers, boiler trim, and accessories.

a. Include plans, elevations, sections, and mounting details.

b. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

c. Include diagrams for power, signal, and control wiring.

4. Warranty: Provide sample of manufacturer's warranty.

5. Seismic Qualification Certificates: Provide certification for the equipment and its components and accessories that they have been tested and meet the requirements for use in seismic applications in accordance with Virginia Construction Code.

B. Construction Submittals:

1. Manufacturer Start-Up Certification: Provide manufacturer's complete start-up procedure including verification and results of each step with dated signatures of the manufacturer's technician who performed the work and the installing contractor's supervisor who witnessed the work. The start-up procedure shall include an inspection to verify it meets the manufacturer's installation requirements.

2. Commissioning Agent Certification: Provide owner's commissioning agent's certification that boiler is installed and operating as intended.

C. Close-Out Submittals:

1. Operation and Maintenance Manuals: Provide operation and maintenance information for standard and emergency operation to be included in the Operation and Maintenance Manuals.

1.3. QUALITY ASSURANCE

A. ASME Compliance: Fabricate and label boilers to comply with 2010 ASME Boiler and Pressure Vessel Code.

B. Efficiencies shall comply with the State Energy Conservation Code.

C. Boilers shall comply with UL-795. They shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.

D. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

E. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

F. Boilers and their installation shall comply with the State Mechanical, Fuel Gas and Fire Codes.

G. Boilers with fuel input ratings up to 12,500 MBH shall comply with ASME CSD-1 and with ratings over 12,500 MBH shall comply with NFPA 85.

1.4. WARRANTY

A. Manufacturer's Warranty: Provide manufacturer's warranty to repair or replace components of the boilers that fail in materials or workmanship within specified warranty period. Warranty period shall start at the date of Owner Acceptance. Warranty repairs and replacements shall include all parts and labor.

1. Heat Exchanger: 10-years
2. Heat Exchanger: 5 years for corrosion and 10 years for thermal shock and stress.
3. Control Board: 5 years
4. All Other Components: Whichever is greater, 1 year from startup or 18 months from shipment after Owner Acceptance.

PART 2 - PRODUCTS

2.1. CONDENSING BOILERS

A. Manufacturers: Provide full-condensing boilers with stainless steel primary or secondary heat exchangers that comply with the construction documents and are manufactured by one of the following:

1. Aerco (AM series)
2. Lochinvar (FTXL series)
3. Weil-McLain (SVF series)

B. Description: Factory-fabricated, -assembled, and -tested, gas-fired condensing-style water heating boiler with heat exchanger sealed pressure tight, built on a steel base, including insulated jacket; flue-gas vent; combustion-air intake connections; water supply, return, and condensate drain connections; and controls.

C. Heat Exchanger: Fire-tube style heat exchanger designed for condensed flue gas shall be constructed of stainless steel.

D. Heat Exchanger: Cast-aluminum heat exchanger designed for condensed flue gas.

E. Heat Exchanger: Water-tube heat exchanger designed for condensed flue gas shall be constructed of stainless steel.

F. Heat Exchanger: Primary or secondary heat exchanger designed for condensed flue gas shall be constructed of stainless steel.

G. Burner: Natural or propane gas as scheduled, forced-draft burner with 20 to 100 percent minimum firing rate modulation.

H. Blower: Centrifugal fan to operate during each burner firing sequence.

I. Gas Train: Combination gas valve with manual shutoff and pressure regulator.

1. Provide additional external gas pressure regulator if needed to provide the most reliable and stable boiler operation based on manufacturer recommendations. Coordinate boiler with service gas pressure. Gas regulators shall be vented to a safe location exterior to the building. Ventless regulators with vent limiters are not acceptable.

J. Ignition: Silicon carbide hot-surface ignition that includes flame safety supervision and 100 percent main-valve shutoff.

K. Casing:

1. Jacket: Sheet metal, with snap-in or interlocking closures.
2. Control Compartment Enclosures: NEMA 250, Type 1A.
3. Finish: Textured epoxy.
4. Insulation: Minimum 1-inch thick, mineral-fiber insulation surrounding the heat exchanger.
5. Combustion-Air Connections: Inlet and vent duct collars.

L. Combustion Efficiency at AHRI Conditions: As scheduled.

2.2. TRIM

A. Include devices sized to comply with ASME B31.9.

B. Safety Relief Valve: ASME rated.

C. Pressure and Temperature Gage: Minimum 3-1/2-inch diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges, so normal operating range is about 50 percent of full range.

D. Boiler Air Vent: Automatic.

E. Drain Valve: Minimum 3/4-inch hose-end gate valve.

F. Circulation Pump: Refer to Section 232123 for pump requirements.

2.3. CONTROLS

A. Boiler factory-installed operating controls shall include the following features:

1. Control transformer.

2. Set-Point Input (adjustable).

3. Enable / Disable Input.

4. Status and Alarm Outputs.

5. Cascading Controls: Each boiler shall have a built-in cascading sequencer. For installations with multiple boilers, a single boiler shall act and the primary master cascading sequencer. Remaining boilers shall follow the master sequencer to maintain redundancy, lead / lag order, and efficiency optimization. The primary boiler controller shall have the capability to control all operation and energy input of the boiler system in conjunction with input from the BAS.

a. When set on Internal Set point Mode, temperature control set points on the boiler shall be fully field adjustable from 90 deg F to 200 deg F in operation.

b. When set on internal Outdoor Air Reset Mode, the boiler shall be capable of resetting header temperature based on outside air temperature. Reset ratio shall be fully field-adjustable from 0.3 to 3.0 in operation.

c. The boiler shall operate to vary header temperature set point linearly as an externally applied 4m to 20ma signal (or similar) is supplied by the BAS. Main Header outlet temperature shall not be more than plus/minus 2 deg F from set point at any point of operation. The external signal will allow full remote control of boiler header temperature by the BAS. Control limitations of minimum or maximum boiler water temperatures will be the full responsibility of the boiler manufacturer. Remote monitoring of alarms shall be required.

B. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.

1. High Cutoff: Automatic reset stops burner if operating conditions rise above maximum boiler design temperature.

2. Low-Water Cutoff Switch: Electronic probe shall prevent burner operation on low water. Cutoff switch shall be automatic-reset type.

3. Blocked Inlet Safety Switch: Manual-reset pressure switch field mounted on boiler combustion-air inlet.

C. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms. Communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

1. BACnet per ASHRAE 135 communication interface with the BAS shall enable the BAS operator to remotely control and monitor the boiler from an operator workstation. All control features and monitoring points displayed locally at boiler control panel shall be available through the BAS.

2.4. ELECTRICAL POWER

A. Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.

2.5. VENTING

A. Combustion-Gas Vent: Provide complete system, ASTM A 959, Type 29-4C stainless steel, pipe and vent terminal that is listed for use with the boiler for the project’s application. Provide connection thimble, indoor plate, vent adapter, condensate trap and neutralization tank, and sealant.

B. Combustion-Air Intake: Provide complete system, stainless steel, PVC, CPVC, or Polypropylene vent terminal that is listed for use with the boiler for the project’s application. Provide with screen, inlet air coupling, and sealant.

2.6. SOURCE QUALITY CONTROL

A. Burner and Hydrostatic Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.

B. Test and inspect factory-assembled boilers, before shipping, according to 2010 ASME Boiler and Pressure Vessel Code.

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting performance of the Work.

1. Final boiler locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.

B. Examine mechanical spaces for suitable conditions where boilers will be installed.

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

3.2. BOILER INSTALLATION

A. Equipment Mounting: Install boilers on 4-inch tall light-weight cast-in-place concrete equipment base(s). Install vibration isolation and/or seismic restraint devices per Section 230548.

B. Install gas-fired boilers according to NFPA 54 and State Fuel Gas Code.

C. Assemble and install boiler trim.

D. Install electrical devices furnished with boiler but not specified to be factory mounted.

E. Install control wiring to field-mounted electrical devices.

3.3. CONNECTIONS

A. Install piping adjacent to boiler to allow service and maintenance.

B. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.

C. Connect piping to boilers, except safety relief valve connections, with flexible connectors of materials suitable for service.

D. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas-train connection. Provide a reducer if required.

E. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve and union or flange at each connection.

F. Install piping from safety relief valves to nearest floor drain.

G. Install flue venting and combustion-air intake.

H. Ground equipment consistent with the requirements of Division 26.

I. Connect wiring consistent with the requirements of Division 26.

3.4. FIELD QUALITY CONTROL

A. Manufacturer Inspection and Start-Up: A Factory-authorized and trained service representative shall test and inspect equipment, components, assemblies and their installations including connections. The representative shall perform the following tests and inspections:

1. Perform installation and startup checks according to manufacturer's written instructions.

2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.

3. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.

4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

    a. Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and water temperature.

    b. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

B. Boiler will be considered defective if it does not pass tests and inspections.

C. Provide test and inspection reports within 30 days of completion and manufacturer approval.

D. Occupancy Adjustments: Upon request within 1 year from the date of owner accepted completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to four (4) owner requested visits to project site for this purpose.

3.5. DEMONSTRATION

A. Engage a factory-authorized service representative to train owner's maintenance personnel to adjust, operate, and maintain boilers. Refer to Section 230200 for demonstration and training requirements.

END OF SECTION

SECTION 23 64 26 – AIR-COOLED CHILLERS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes packaged, air-cooled, electric motor driven chillers.

1.2. PERFORMANCE REQUIREMENTS

A. Seismic Performance: Centrifugal chillers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

B. Site Altitude: Chiller shall be suitable for altitude in which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude of 2100 ft.

1.3. SUBMITTALS

A. Product Submittals:

1. Product Data: For each type of product indicated include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.

a. Performance at ARI standard conditions and at conditions indicated.

b. Performance at ARI standard unloading conditions.

c. Minimum evaporator flow rate.

d. Refrigerant capacity of chiller.

e. Oil capacity of chiller.

f. Fluid capacity of evaporator.

g. Characteristics of safety relief valves.

h. Minimum entering condenser-air temperature.

i. Maximum entering condenser-air temperature.

j. Performance at varying capacities with constant-design entering condenser-air temperature. Repeat performance at varying capacities for different entering condenser-air temperatures from design to minimum in 5 deg F increments.

k. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

l. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.

m. Wiring Diagrams: For power, signal, and control wiring.

2. Warranty: Sample of special warranty.

B. Close-Out Submittals:

1. Operation and Maintenance Data: For each chiller to include in emergency, operation, and maintenance manuals.

1.4. EXTRA MATERIALS

A. Extra Stock: Provide owner with the following extra materials:

1. Quart container of paint used in application of topcoat to use in touchup applications.

1.5. QUALITY ASSURANCE

A. ARI Certification: Certify chiller according to AHRI 590 certification program(s).

B. ASME Compliance: Fabricate and label chiller to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and include an ASME U-stamp and nameplate certifying compliance.

C. Efficiencies shall comply with the State Energy Conservation Code.

D. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

E. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

1.6. DELIVERY, STORAGE, AND HANDLING

A. Ship each chiller with a full charge of refrigerant. Charge each chiller with nitrogen if refrigerant is shipped in containers separate from chiller.

B. Ship each oil-lubricated chiller with a full charge of oil.

1.7. COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.

1.8. WARRANTY

A. Special Warranty: Manufacturer’s complete machine parts, labor and refrigerant warranty for 5-years from the date of Owner Acceptance.

PART 2 - PRODUCTS

2.1. GENERAL REQUIREMENTS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following for scroll-type compressor chillers:

1. Carrier (30R Series)
2. Daikin-McQuay (AGZ Series)
3. Dunham Bush (ACDS Series)
4. Johnson Controls/York (YCAL or YMAE Series depending upon availability during ongoing EPA refrigerant transition period)
5. Trane (CGAM Series)

2.2. PACKAGED, AIR-COOLED CHILLERS

A. Description: Factory-assembled and run-tested chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.

B. Cabinet: Chiller cabinet shall be manufacturer’s standard galvanized steel construction with corrosion protection coating and exterior finish.

1. Architectural Louvered Panels: Provide unit with louvered panels that completely cover the condenser coils and service areas beneath the condenser coils.

C. Enhanced Sound-Reduction: Factory provided and field installed package designed to reduce sound level without affecting performance, including an added acoustic enclosure around compressors, reducing fan speeds and acoustically treating fans.

2.3. CHILLERS WITH SCROLL COMPRESSORS

A. Compressors: Positive displacement, direct-drive, semi-hermetic compressors with precision-machined cast-iron casing and manufacturer’s standard scroll design. Each compressor shall be equipped with suction and discharge shut-off valves, crankcase oil heater and suction strainer.

1. Capacity Control: On-off compressor cycling with hot-gas bypass or digital compressor unloading.
2. Oil Lubrication System: Consisting of automatic pump with strainer, sight-glass, filling connection, filter with magnetic plug, and initial oil charge.
3. Compressor Motors: High-torque, two-pole induction type motors with inherent thermal-overload protection on each phase and hermetically sealed and cooled by refrigerant suction gas.
4. Compressor Motor Controllers: Across-the-Line NEMA ICS 2, Class A, full-voltage, non-reversing.”

B. Refrigerant Circuits:

1. Refrigerant: R-454B or R-32
2. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.

3. Refrigerant Circuit: Each shall include a thermal- or electronic-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.

4. Pressure Relief Valves: ASME-rated, spring-loaded, multi-reseating type pressure relief valves shall be provided for each heat exchanger. Comply with ASHRAE 15, ASHRAE 147 and applicable portions of ASME Boiler and Pressure Vessel Code.

C. Evaporator: Brazed-plate or shell-and-tube design, as indicated.

1. Shell and Tube Type: Direct-expansion, shell-and-tube design, tested and stamped according to ASME Boiler and Pressure Vessel Code.

a. Shell Material: Carbon steel.

b. Shell Heads: Removable carbon-steel heads with multi-pass baffles designed to ensure positive oil return and located at each end of the tube bundle.

c. Shell Nozzles: Fluid nozzles located along the side of the shell and terminated with mechanical-coupling end connections for connection to field piping.

d. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.

2. Brazed Plate Type: Direct-expansion, single-pass, brazed-plate design, tested according to ASME Boiler and Pressure Vessel Code.

a. Plate Material: Type 304 or 316 stainless-steel construction.

b. Fluid Nozzles: Terminate with mechanical-coupling end connections for connection to field piping.

c. Inlet Strainer: Factory-furnished, 40-mesh strainer for field installation in supply piping to evaporator.

3. Flow Switch: Factory furnished and field installed, thermal-type flow switch wired to chiller operating controls.

4. Heater: Factory-installed and -wired electric heater with integral controls designed to protect the evaporator to minus 20 deg F.

D. Air-Cooled Condenser:

1. Coil(s) with integral sub-cooling on each circuit.

2. Copper Tube with Plate Fin Coils: Coils constructed of copper tubes mechanically bonded to aluminum fins.

3. Aluminum Microchannel Coils: Coils constructed of a series of flat tubes containing a series of multiple, parallel-flow microchannels layered between refrigerant header manifolds. Fins, tubes, and header manifolds shall be constructed of aluminum alloy treated with a corrosion-resistant coating.

4. Corrosion-Resistant Coating: Coat coils with an epoxy or a phenolic corrosion-resistant coating after fabrication.

5. Hail Protection: Provide condenser coils with louvers, baffles, or hoods to protect against hail damage.

6. Fans and Fan Motors: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge. Refer to Sections 230513 and 233416.

7. Fan Guards: Removable steel safety guards with corrosion-resistant coating.

E. Electrical Power: Factory installed and wired switches, motor controllers, transformers, and other electrical devices necessary to provide a single-point field power connection. Wiring shall be numbered and color-coded to match wiring diagram. Electrical equipment shall be mounted in a NEMA 250, Type 3R enclosure with hinged access door, lock and key. Factory installed wiring located outside the enclosure shall be routed in metallic raceway with no more than 24-inch length of liquid-tight or flexible metallic conduit at connections.

1. Field power interface shall be to NEMA 1, heavy-duty, non-fused disconnect switch. Minimum SCCR according to UL 508 shall be as required by electrical power distribution system, but not less than 65,000A.

2. Each motor shall have branch power circuit and controls with fused disconnect switch or circuit breaker disconnecting means with SCCR to match main disconnecting means: Each motor shall have overcurrent protection. Overload relay shall be sized according to UL 1995 or be an integral component of water chiller control microprocessor.

3. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.

4. Power Factor Correction: Capacitors to correct power factor to 0.95 at full load.

5. Controls Power: Provide unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity and auxiliary and adjustable time-delay relays or an integral to water chiller microprocessor.

6. User Interface: Indicate the following for water chiller electrical power supply:

    a. Current, phase to phase, for all three phases.

    b. Voltage, phase to phase and phase to neutral for all three phases.

    c. Three-phase real power (kilowatts).

    d. Three-phase reactive power (kilovolt amperes reactive).

    e. Power factor.

    f. Running log of total power versus time (kilowatt hours).

    g. Fault log, with time and date of each.

F. Controls: Factory installed, wired, and functionally tested standalone, microprocessor based controls with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power. Controls shall share enclosure with electrical power devices or provide a separate enclosure of matching construction.

1. Operator Interface: Keypad or pressure-sensitive touch screen with multiple-character digital display. Display the following:

a. Date and time.

b. Operating or alarm status.

c. Operating hours.

d. Outside-air temperature if required for chilled-water reset.

e. Temperature and pressure of operating set points.

f. Chilled-water entering and leaving temperatures.

g. Refrigerant pressures in evaporator and condenser.

h. Saturation temperature in evaporator and condenser.

i. No cooling load condition.

j. Elapsed time meter (compressor run status).

k. Pump status.

l. Anti-recycling timer status.

m. Percent of maximum motor amperage.

n. Current-limit set point.

o. Number of compressor starts.

p. Alarm history with retention of operational data before unit shutdown.

q. Superheat.

2. Control Functions:

a. Manual or automatic startup and shutdown time schedule.

b. Capacity control based on evaporator leaving-fluid temperature.

c. Capacity control compensated by rate of change of evaporator entering-fluid temperature.

d. Chilled-water entering and leaving temperatures, control set points, and motor load limit.

e. Current limit and demand limit.

f. External water chiller emergency stop.

g. Anti-recycling timer.

h. Automatic lead-lag switching.

3. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:

a. Low evaporator pressure or high condenser pressure.

b. Low chilled-water temperature.

c. Refrigerant high pressure.

d. High or low oil pressure.

e. High oil temperature.

f. Loss of chilled-water flow.

g. Control device failure.

4. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.

   a. BACnet per ASHRAE 135 communication interface with the BAS shall enable the BAS operator to remotely control and monitor the chiller from an operator workstation. All control features and monitoring points displayed locally at chiller control panel shall be available through the BAS.

   b. Hardwired I/O Points:

      1) Monitoring: On/off status, common trouble alarm, electrical power demand, and electrical power consumption.

      2) Control: On/off operation, chilled-water discharge temperature set-point adjustment, and electrical power demand limit.

5. Factory-installed wiring outside of enclosures shall be in NFPA 70-complaint raceway. Make terminal connections with liquid-tight or flexible metallic conduit.

G. Insulation: Closed-cell, flexible, elastomeric thermal insulation complying with ASTM C 534/C 534M, Type I for tubular materials and Type II for sheet materials. Factory-apply insulation over all cold surfaces of chiller capable of forming condensation. Components shall include evaporator, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.

1. Thickness: 3/4-inch, minimum.

2. Paint: After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

2.4. SOUND REDUCTION FEATURES

A. Sound Reduction Features: Provide factory installed or factory-fabricated and field installed accessories from the chiller manufacturer designed to reduce noise from the standard product.

1. Compressor Muffler

2. Low Noise Condenser Fans

3. Refrigerant Piping Sound Absorption Insulation

4. Condenser Fan Speed Control

2.5. SOURCE QUALITY CONTROL

A. Perform functional tests of chillers before shipping.

B. Factory run test each air-cooled chiller with water flowing through evaporator.

C. Factory test and inspect evaporator and condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

D. For chillers located outdoors, rate sound power level according to ARI 370.

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine chillers before installation. Reject chillers that are damaged.

B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.

1. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.

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

3.2. CHILLER INSTALLATION

A. Equipment Mounting:

1. Install chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations.

2. Comply with requirements for vibration isolation and seismic control devices specified in Section 230548.

B. Maintain manufacturer's recommended clearances for service and maintenance.

C. Charge chiller with refrigerant and fill with oil if not factory installed.

D. Install separate devices furnished by manufacturer and not factory installed.

3.3. CONNECTIONS

A. Comply with requirements for piping specified in Section 232113 and 232116. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to chiller to allow service and maintenance.

C. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, strainer, flexible connector, thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, flexible connector, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, and drain connection with valve. Make connections to chiller with a flange.

3.4. 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.
2. Verify that refrigerant charge is sufficient and chiller has been leak tested.
3. Verify that pumps are installed and functional.
4. Verify that thermometers and gages are installed.
5. Operate chiller for run-in period.
6. Check bearing lubrication and oil levels.
7. For chillers installed indoors, verify that refrigerant pressure relief device is vented outdoors.
8. Verify proper motor rotation.
9. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.
10. Verify and record performance of fluid flow and low-temperature interlocks for evaporator.
11. Verify and record performance of chiller protection devices.
12. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.

C. Prepare test and inspection startup reports.

3.5. DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain chillers.

END OF SECTION

SECTION 23 82 16 – AIR COILS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes heating and cooling air coils.

1.2. SUBMITTALS

A. Product Submittals: For each type of product include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each air coil. Include rated capacities, operating characteristics, and pressure drops for each air coil.

1.3. QUALITY ASSURANCE

A. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

B. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

PART 2 - PRODUCTS

2.1. GENERAL REQUIREMENTS

A. Performance Ratings: Hydronic, steam and refrigerant coils shall be tested and rated according to AHRI 410 and ASHRAE 33. Electric resistance coils shall be listed and labeled according to NFPA 70 and assembled according to UL 1995.

2.2. HYDRONIC COILS

A. Description: Coils shall be factory tested to 300 psig and rated for a minimum working pressure of 200 psig and minimum temperature of 325 deg F. Coil tubes shall be ASTM B 743 seamless copper expanded into fin collars for permanent fin-tube bond and expanded into header for permanent leak-tight joints. Coil fins shall be copper or aluminum. Coil headers shall be cast-iron with drain and air vent tappings for coils 32-inches tall and less and seamless copper tube with brazed joints and prime coated for coils taller than 32-inches. Coil casings shall be minimum 16 gauge galvanized steel channel frame for slip-in or flanged mounting.

2.3. REFRIGERANT COILS

A. Description: Coils shall be factory tested to 450 psig and rated for a minimum working pressure of 300 psig. Coil tubes shall be ASTM B 743 seamless copper expanded into fin collars for permanent fin-tube bond and expanded into header for permanent leak-tight joints. Coil fins shall be copper or aluminum. Suction and distribution piping shall be ASTM B 88, Type L copper tube with brazed joints. Coil casings shall be minimum 16 gauge galvanized steel channel frame for slip-in or flanged mounting.

2.4. ELECTRIC RESISTANCE COILS

A. Description: Heating elements shall be open-coil resistance wire of 80 percent nickel and 20 percent chromium, supported and insulated by floating ceramic bushings recessed into casing openings, and fastened to supporting brackets. Coil casings shall be minimum 16-gauge galvanized steel channel frame for slip-in or flanged mounting.

1. High-Temperature Coil Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or casing.
2. Secondary Protection: Load-carrying, manually reset or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
3. Control Panel: Unit- mounted with disconnecting means and overcurrent protection with SCR modulating control; non-fused safety disconnect switch interlocked with heater terminal box cover; adjustable air flow proving switch; time delay relay; differential pressure switch; 24V control transformer; and automatic reset thermal cutouts pre-wired to the control circuit.
4. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70 by a qualified testing agency accepted by the Authority Having Jurisdiction and marked for intended location and application.

2.5. DRAIN PANS

A. Description: Drain pans shall be stainless steel. Alternative materials, such as galvanized steel and plastic, are not acceptable. Construct insulated pans with drain connection at the lowest point(s) and comply with ASHRAE 62.1. Pans shall extend beyond coil length and width, upstream and downstream of coil face, and under coil header and exposed piping

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance.

B. Examine roughing-in for piping systems to verify actual locations of piping connections before coil installation.

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

3.2. INSTALLATION

A. Install coils level and plumb.

B. Install coils in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."

C. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

D. Install drain pan under each cooling coil. Connect to condensate trap and drainage.

E. Straighten bent fins on air coils.

3.3. CONNECTIONS

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to coils to allow service and maintenance.

C. Hydronic Coils: Connect water piping with unions and shutoff valves to allow coils to be disconnected without draining piping. Control valves are specified in Section 239010 and other piping specialties are specified in Section 232116.

D. Refrigerant Coils: Connect refrigerant piping according to Section 232300.

E. Electric Resistance Coils: Ground equipment and connect wiring in accordance with NFPA 70 and Division 26.

END OF SECTION

SECTION 23 82 39 – UNIT HEATERS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes propeller unit heaters with hot-water and electric-resistance heating coils.

1.2. SUBMITTALS

A. Product Submittals: For each type of product indicated include rated capacities, operating characteristics, furnished specialties, and accessories.

B. Close-Out Submittals:

1. Operation and Maintenance Data: For propeller unit heaters to include in emergency, operation, and maintenance manuals.

1.3. QUALITY ASSURANCE

A. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

B. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

PART 2 - PRODUCTS

2.1. MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by the following for electric resistance unit heaters:

1. Markel
2. Modine
3. Reznor
4. Trane

B. Manufacturers: Subject to compliance with requirements, provide products by the following for hydronic unit heaters:

1. Modine
2. Sterling

3. Trane

4. Vulcan Radiator

2.2. DESCRIPTION

A. Assembly including casing, coil, fan, and motor in vertical and horizontal discharge configuration with adjustable discharge louvers.

2.3. HOUSINGS

A. Finish: Manufacturer's standard baked enamel applied to factory-assembled and -tested propeller unit heaters before shipping.

B. Discharge Louver: Adjustable fin diffuser for horizontal units and conical diffuser for vertical units.

2.4. COILS

A. General Coil Requirements: Test and rate hot-water propeller unit-heater coils according to ASHRAE 33.

B. Hot-Water Coil: Copper tube minimum 0.025-inch wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 325 deg F, with manual air vent. Test for leaks to 350 psig underwater.

C. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and 60-Hz hum, embedded in magnesium oxide refractory and sealed in steel or corrosion-resistant metallic sheath with fins no closer than 0.16 inch. Element ends shall be enclosed in terminal box. Fin surface temperature shall not exceed 550 deg F at any point during normal operation.

1. Circuit Protection: One-time fuses in terminal box for overcurrent protection and limit controls for high-temperature protection of heaters.

2. Wiring Terminations: Stainless-steel or corrosion-resistant material.

2.5. FAN AND MOTOR

A. Fan: Propeller type with aluminum wheel directly mounted on motor shaft in the fan venturi.

B. Motor: Comply with requirements in Section 230513.

2.6. CONTROLS

A. Control Devices: Unit-mounted adjustable thermostat.

PART 3 - EXECUTION

3.1. EXAMINATION

A. Examine areas to receive propeller unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for piping and electrical connections to verify actual locations before unit-heater installation.

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

3.2. INSTALLATION

A. Install propeller unit heaters to comply with NFPA 90A.

B. Install propeller unit heaters level and plumb.

C. Suspend propeller unit heaters from structure with all-thread hanger rods and elastomeric hangers. Hanger rods and attachments to structure are specified in Section 230529. Vibration hangers are specified in Section 230548.

D. Install switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with drawings and room details before installation.

3.3. CONNECTIONS

A. Piping installation requirements are specified in Section 232113 and 232116 for hydronic coils. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to machine to allow service and maintenance.

C. Connect piping to propeller unit heater's factory, hot-water piping package. Install the piping package if shipped loose.

D. For hydronic unit heaters, comply with safety requirements in UL 1995.

E. Unless otherwise indicated, install union and gate or ball valve on supply-water connection and union and calibrated balancing valve on return-water connection of propeller unit heater. Hydronic specialties are specified in Section 232113 and 232116.

F. Ground equipment according to Division 26.

G. Connect wiring according to Division 26.

3.4. FIELD QUALITY CONTROL

A. Perform the following tests and inspections.

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

2. Operate electric heating elements through each stage to verify proper operation and electrical connections.

3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

3.5. DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain propeller unit heaters.

END OF SECTION

SECTION 23 90 00 – BAS GENERAL REQUIREMENTS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes general requirements for control systems.

1.2. DESCRIPTION OF WORK

A. The Building Automation System (BAS) contractor shall provide including but not limited to sensors, devices, field controllers and panels, network controllers and servers, integration with existing campus front end operator interface, software and any other hardware or software components for a fully functioning BAS system.

B. Provide graphics on the front-end server for each piece of equipment, terminal unit, and system.

C. Provide BAS Commissioning. The process of ensuring that all building systems are installed and perform interactively according to the design intent, the systems are efficient and cost effective and meet the owner's operational needs, the installation is adequately documented, and that the Operators are adequately trained. It serves as a tool to minimize post-occupancy operational problems. It establishes testing and communication protocols in an effort to advance the building systems from installation to full dynamic operation and optimization.

D. Engineer/Commissioning Authority (CA) and Owner shall work with the Contractor and direct, coordinate, and oversee the Commissioning process and witness functional performance testing. Contractor is required to coordinate with both the Owner and CA to conduct the work and provide sufficient notification to both parties for all activities related to commissioning.

E. BAS Architecture Description: Radford University has a dual-source BAS provider, including Johnson Controls and Automated Logic. Each system is equipped with a separate campus automation system front end server. The control system for this project shall be based on one of the two BAS providers and shall be fully integrated with the existing campus server. All systems must be completely and seamlessly programmable through the graphical workstations, through use of open protocol controllers, or gateways. Each Network Control Unit (NCU) panel must have an "open programming license" so that all approved integrators will have the ability for programming modifications.

1. The building BAS shall connect to the existing university by means of the existing campus Ethernet system. This connection will be provided by the Owner. Contractor shall provide temporary cabling, power, and connections during construction to maintain continuous connectivity to the university system

2. Systems that require additional computers or software to program and control will not be acceptable. The Contractor must provide the cost for the complete integration of the new system open protocol controller and/or gateway to the existing system interface.

3. Graphics, trends, alarms, etc. shall be located on individual NCUs and pushed to the Supervisor.

4. The BAS system shall be designed, installed, commissioned, and serviced by factory-trained personnel employed by the manufacturer. Manufacturer shall have an in-place support facility within one hundred twenty (120) miles of the project site with trained staff, spare parts inventory and necessary test and diagnostics equipment.

5. The system shall have a documented history of compatibility by design for a minimum of fifteen (15) years. Future compatibility shall be supported for no less than ten (10) years. Compatibility shall be defined as the ability to upgrade existing field panels and extend new field panels on a previously installed network.

6. Preprogrammed standalone single- or multi-loop microprocessor proportional-integral-derivative (PID) controllers must be provided to control all HVAC, electric, and plumbing subsystems as described.

7. All chillers, boilers, terminal units, and air handling units must have self-contained BACnet controllers which must communicate to the Radford University BAS through either BACnet MSTP or Modbus-485.

8. The installed components of the BAS must have twenty percent (20%) spare capacity for future expansion.

9. Provide additional licensing as required to integrate new controllers to existing front end.

10. Coordinate with owner for additional IP addresses as needed.

1.3. SUBMITTALS

A. Qualification Submittals: For installer.

B. Product Submittals:

1. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, installation guides, and startup instructions for each type of product indicated.

   a. BAS System Hardware: Bill of materials of equipment indicating quantity, manufacturer, and model number. Include technical data for operator workstation equipment, interface equipment, control units, transducers/transmitters, sensors, actuators, valves, relays/switches, control panels, and operator interface equipment.

   b. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

   c. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.

2. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

   a. Bill of materials of equipment indicating quantity, manufacturer, and model number.

b. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.

c. Wiring Diagrams: Power, signal, and control wiring.

d. Details of control panel faces, including controls, instruments, and labeling.

e. Written description of sequence of operation.

f. Schedule of dampers including size, leakage, and flow characteristics.

g. Schedule of valves including flow characteristics, pressure differentials, and flow coefficients (Cv).

h. BAS System Hardware:

1) Wiring diagrams for control units with termination numbers.

2) Schematic diagrams and floor plans for field sensors and control hardware.

3) Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between operator workstation and control unit locations.

i. Control System Software: List of color graphics indicating monitored systems, data (connected and calculated) point addresses, output schedule and operator notations.

j. Controlled Systems:

1) Schematic diagrams of each controlled system with control points labeled and control elements graphically shown, with wiring.

2) Scaled drawings showing mounting, routing, and wiring of elements including bases and special construction.

3) Written description of sequence of operation including schematic diagram.

4) Points list.

k. Samples for Verification: For each color required, of each type of thermostat or sensor cover.

3. Display Graphics: Provide a sample of proposed display graphics for each screen page and a flowchart diagram showing how each screen will be linked to the other. Where there are multiple systems or equipment that are repetitive, it is acceptable to provide one and note it applies to others. For example, one terminal unit screen graphic may be submitted as an example to represent all the terminal units of that type for the project.

a. Owner’s Graphic Standards: The owner’s graphic standards shall be followed.

4. Provide a complete list of any deviations of submitted products to the specification in this document.

5. Data Communications Protocol Certificates: Certify that each proposed BAS system component complies with ASHRAE 135 (BACnet), ANSI Standard ANSI/CEA-709.1 (LonTalk), or MODBUS protocol specification conformance, as applicable.

6. Listing of Products: Certify that each proposed BAS system component is listed with BACnet Testing Lab (BTL), are marked with "LONMARK Compliant" and display the "LONMARK" logo or have been tested per the Modbus Conformance Testing Program, as applicable.

7. Seismic Qualification Certificates: Provide certification for the equipment and its components and accessories that they have been tested and meet the requirements for use in seismic applications in accordance with Virginia Construction Code.

C. Construction Submittals:

1. Checkout Sheets

a. Prior to startup of any equipment, contractor will provide manufacturer checkout sheets for each piece of equipment.

b. Checkout sheets will contain at a minimum:

1) Equipment name and location.

2) Associated controller address (MAC or Node ID), name, type and instance number.

3) Provide documentation of testing and calibration for each input and output. Submit for Engineer review.

D. Close-Out Submittals:

1. Operation and Maintenance Data: For HVAC instrumentation and control system to include in emergency, operation, and maintenance manuals, including the following:

a. Maintenance instructions and lists of spare parts for each type of control device.

b. Interconnection wiring diagrams with identified and numbered system components and devices.

c. Keyboard illustrations and step-by-step procedures indexed for each operator function.

d. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.

e. Calibration records and list of set points.

f. BAS Checkout Report: Controls system point-to-point checkout list to include the following: all physical points (excluding software points and/or setpoints), technician's initials, and dates of the point checkout.

g. Contractor verification of 100 percent of all control and monitoring points and all control sequences prior to Engineer witness.

2. Software and Firmware Operational Documentation: Include the following:

a. Software operating and upgrade manuals for all software required to program and maintain the system.

b. Program Software Backup: On a magnetic media or compact disc, complete with data files.

c. Device address list.

d. Printout of software application and graphic screens.

e. Software license required by and installed for BAS workstations and control systems.

3. Software Back-Up Electronic Files.

1.4. QUALITY ASSURANCE

A. The building automation system (BAS) shall be furnished, engineered, installed, tested and calibrated by factory certified technicians qualified for this work. The contractor shall be factory authorized in good standing with the manufacturer and located within 100 miles of the project site. Factory trained technicians shall provide instruction, routine maintenance, and emergency service within 24 hours upon receipt of request. A full-time on-site experienced project manager for this work shall be responsible for the direct supervision of the installation and start-up of the system.

1. Upon request, installer shall present records of successful completion of factory training courses.

2. Upon request, the installer shall provide a letter from the manufacturer that they are a Factory Authorized installer in good standing with the Manufacturer.

3. Upon request, the installer shall provide a list of 10 projects of similar scope and complexity within the past 5 years with the project owner's contact information.

B. Comply with UL 916 for Energy Management Systems.

C. Comply with UL 864 for Smoke Control System components.

D. <u>Control panels, new and modified, shall comply with UL 508A. Field-built or modified panels shall be inspected, listed and labeled in the field or replaced with an equivalent shop-built panel that is listed and labeled</u>.

E. Comply with ASHRAE 135 for BAS system components.

1. Local and Terminal Control Units shall be BACnet Testing Lab (BTL) listed.

A. Electrical Components, Devices and Accessories: UL listed and labeled as defined by NFPA 70, the National Electric Code, or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

B. Mechanical Equipment and Materials: UL listed and labeled as defined by State Building Codes or equivalent by a qualified testing agency marked for the intended location and application and accepted by the Authority Having Jurisdiction and Engineer.

1.5. DELIVERY, STORAGE AND HANDLING

A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.

1.6. COORDINATION

A. Coordinate location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation. Verify all locations with Engineer prior to installation.

B. Coordinate equipment with the fire alarm system to achieve compatibility with equipment that interfaces with that system.

C. Coordinate sources of 120V power with the Electrical Contractor and Owner for control units, operator workstation and other devices. Extend power from sources as needed.

D. Coordinate location of data ports with the Electrical Contractor and Owner.

1.7. SEQUENCE OF OPERATION

A. Sequences of Operation are located on the control drawings. Submit standard sequences for incidental items not shown for Engineer approval.

1.8. EXTRA MATERIALS

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. Replacement Materials: One replacement diaphragm or relay mechanism for each unique valve motor, controller, thermostat, humidistat and positioning relay.

1.9. WARRANTY

A. Building Automation System: Parts and labor for 1 year from the date of completion. The Owner reserves the right to make changes to the BAS during the warranty period and such changes do not constitute a waiver of the warranty.

1. The Owner shall allow remote access to the BAS for diagnostic testing and monitoring during the warranty period.
2. Upon request, a technician shall be on site to resolve the Owner reported issue within 24 hours of it being reported if it has not been resolved remotely to the Owner's satisfaction.

B. Electronic Actuators: Parts and labor for 5 years from the date of completion.

PART 2 - PRODUCTS

2.1. GENERAL REQUIREMENTS

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

1. Automated Logic / United Technologies (WebCTRL series) installed by Automated Logic

2. Johnson Controls Inc. (Metasys) installed by Johnson Controls Inc. (JCI).

B. Products by the BAS system manufacturer shall include user interface, controller software, application programming language and equipment and application controllers. Sensors, actuators, valves, dampers and other components may be manufactured by others as indicated.

2.2. GRAPHICS AND REPORTING

A. Floor Plan Graphics:

1. Provide floor plan graphics for all areas of the building(s) served by the BAS. Create floor plans with an appropriate level of detail based on the construction documents. Copying the construction document files is not acceptable as they usually contain too much detail to be legible on a single screen shot. Submit the proposed graphics with the Owner / Engineer for approval.

2. Provide links from floor plans to enlarge floor plan areas (zoom in feature). Provide links from enlarged floor plans to equipment diagrams.

3. Provide links from zone sensor locations on the floor plans to associated terminal equipment. Each temperature control zone shall be clearly indicated on the floor plans.

4. Coordinate room names and numbers with the Owner and building signage. Often the final room names and numbers differ from the construction documents.

B. Equipment / Terminal Unit Graphics:

1. Provide an equipment diagram indicating each component and sensor with a link to the written sequence of operation, maintenance notes, etc. Each diagram shall indicate all data points. Parameters shall be overridden / changed from the graphic.

2. Provide a link to associated equipment for each diagram. (For example, a terminal unit might have a link at the reheat coil to the heating water plant and the terminal box to the AHU feeding it.)

3. Provide a location for any point associated with an equipment diagram but located remotely. For example, a duct-mounted pressure sensor in the AHU diagram might be indicated to be ‘Located AFC in 24x12 SA duct in Corridor 100 outside Room 101’.)

4. Terminal Unit Graphics: Typical terminal unit graphics shall include:

   a. Minimum and maximum flow setpoints

   b. Heating flow setpoints

   c. Zone heating and cooling temperature, high and low humidity and carbon dioxide high limit setpoints (if applicable)

   d. Terminal unit percent of maximum heating and cooling

   e. Occupancy control mode and status

f. Alarm status.

g. Time and date

h. Outside air temperature

C. Alarm Reporting:

1. Alarm Tag: Each alarm shall have a unique description tag, date and time. The tag shall be easily understood without the need to translate abbreviated or coded descriptions. The OWS shall be able to display, print and store each alarm message.

2. Alarm Prioritization: Each alarm type shall be assigned a priority level as defined by the Owner.

3. Alarm Acknowledgment: Each alarm shall be acknowledged by a recipient with password authorization via any form of operator interface. The alarm acknowledgement information including operator, date and time shall be saved with and append the alarm tag.

4. Alarm Summary Logs: Operators shall be able view all alarms and acknowledgements. They shall be sortable by date and time, operator, alarm type, and alarm priority.

5. OWS interface shall monitor all alarms. Alarm notifications shall be automatically sent to Owner staff via email and text messaging based on staff and alarm prioritization. The system's ability to report alarms shall not be affected by a breakdown in communications with other control panels on the network.

6. Alarms shall be defined by the Engineer's sequences of operation and the Owner.

D. Trend Reporting:

1. Trend Tag: Each trend shall have a unique description tag, date and time duration. The tag shall be easily understood without the need to translate abbreviated or coded descriptions. The OWS shall be able to display, print and store trend data.

2. Trend Summary Logs: Operators shall be able view all trend data. They shall be sortable by initiation date and time, operator, trend type.

3. Trend Data Collection: Data shall be exported to a compressed file on the server in MS Excel or MS Access format. Data shall be able to be stored without over-writing the collected data files for no less than one year.

4. Initial trends shall be defined by the Engineer's sequences of operation. Final trends at project completion shall be determined by the Engineer and Owner once the building systems are fully operational and functioning properly.

E. As-Builts:

1. A link to the schematics, wiring diagrams, and sequences of operation in PDF format shall be displayed on the equipment graphic to enable the owner to view them from the graphic interface to assist in troubleshooting of the system.

2.3. UNINTERRUPTABLE POWER SUPPLIES (UPS)

A. Uninterruptable Power Supplies (UPS): Provide individual UPS to maintain system operation for short-term power interruptions up to 30-minutes. Manufactured by APC or Engineer approved equal.

1. Operator Workstation.
2. Servers.
3. Network Control Units (NCU's)
4. Critical Control Panels as defined by the Engineer based on submitted controls architecture.

2.4. SURGE PROTECTION

A. Surge Protection Devices: Provide lightening / surge protection devices to protect the BAS system. Ditek (DTK-LVLP series), Emerson Edco (PC642 series), PE manufacturing (DRS series) or equal.

B. Provide surge protection on the following equipment:

1. Operator Workstation
2. Servers
3. Network Control Units (NCU's)
4. Critical Control Panels as defined by the Engineer based on submitted controls architecture.
5. Control cable, including but not limited to input/output wiring, communication bus, or any other wire at every point it exits and enters the building.

C. Where a UPS is also being provided, it may be combined with the surge protection requirements.

2.5. CONTROL CABLE

A. Electronic and fiber-optic cables for control wiring shall comply with Section 230511 and Division 26.

2.6. ELECTRICAL CONNECTIONS AND ENCLSOSURES

A. Provide 24V transformers for all control equipment fed by low-voltage (100 to 600 V) power feeders. Coordinate the exact requirements with the Electrical Contractor.

B. Comply with the requirements of Section 230511 and Division 26.

PART 3 - EXECUTION

3.1. EXAMINATION

A. Work and/or systems installed under this Division shall be fully functioning prior to demonstration and acceptance. Contractor shall start, test, adjust, and calibrate all work and/or systems under this Contract, as described below.

B. Verify that power supply is available to control units and operator workstation.

C. Verify that duct, pipe, and equipment-mounted devices are installed before proceeding with installation.

3.2. HARDWARE AND SOFTWARE INSTALLATION

A. Install software in NCUs, Operator Workstation(s), Server(s), as required, and in accordance with 239030. Implement all features of programs to specified requirements and as appropriate to sequence of operation.

1. Sequence of operation programming shall exist on the controller level with default values set to allow continuous, stable system operation in case of network failure.

B. Connect and configure equipment and software to achieve sequence of operation specified.

C. Graphics: The web browser view of the graphics shall be the same as provided by the Operator Interface Graphic Software when accessed directly on the Owner's network. The web browser graphics shall support URL hypertext links for other locations on the internet and intranet.

1. All graphic screens shall indicate date, time, and outside air temperature, and outside air relative humidity.

2. All valves and dampers shall display position as percent open.

D. Trending: Unless otherwise noted on construction documents or points lists the following points should be trended at the defined intervals:

1. Analog Inputs: 15 Minute (Max) Interval.

2. Analog Outputs: 15 Minute (Max) Interval.

3. Setpoints: COV and at least once every 24 hours.

4. Digital points: COV and at least once every 24 hours.

3.3. ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. Extend 120V power circuits from points provided to control voltage transformers. Where dedicated junction boxes have been provided, coordinate the exact locations with the Electrical Contractor. Where they have not, coordinate the spare circuit breakers to be used with the Electrical Contractor or Owner.

B. Install raceways, boxes, and cabinets according to Section 230511 and Division 26.

C. Install building wire and cable according to Section 230511 and Division 26.

D. Install signal and communication cable according to Section 230511 and Division 26. Comply with manufacturer's installation guidelines.

1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.

2. Install exposed cable in raceway.

3. Install concealed cable in raceway.

4. Bundle and harness multi-conductor instrument cable in place of single cables where several cables follow a common path.

5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.

6. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.

7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.

E. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.

F. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

G. Install surge protection in accordance with manufacturer’s guidelines.

3.4. FIELD QUALITY CONTROL

A. Description: Inspect, test, verify and demonstrate equipment, control components and sequences of operation device-by-device and line-by-line for Engineer approval prior to Owner Acceptance.

1. Coordinate efforts with the Owner, Engineer, Commissioning Agent (if applicable), Construction Manager, Mechanical Contractor, Fire Alarm Contractor and TAB Contractor.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.

1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.

2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Testing:

1. Perform preinstallation, in-progress, and final tests, supplemented by additional tests, as necessary.

2. Preinstallation Cable Verification: Verify integrity and serviceability for new cable lengths before installation. This assurance may be provided by using vendor verification documents, testing, or other methods. As a minimum, furnish evidence of verification for cable attenuation and bandwidth parameters.

3. In-Progress Testing: Perform standard tests for correct pair identification and termination during installation to ensure proper installation and cable placement. Perform tests in addition to those specified if there is any reason to question condition of material furnished and installed. Testing accomplished is to be documented by agency conducting tests. Submit test results for Project record.

4. Final Testing: Perform final test of installed system to demonstrate acceptability as installed. Testing shall be performed according to a test plan supplied by BAS system manufacturer. Defective Work or material shall be corrected and retested. As a minimum, final testing for cable system, including spare cable, shall verify conformance of attenuation, length, and bandwidth parameters with performance indicated.

5. Test Equipment: Use an optical fiber time domain reflectometer for testing of length and optical connectivity.

6. Test Results: Record test results and submit copy of test results for Project record.

3.5. BAS SYSTEM VERIFICATION

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

B. Check instruments for proper location and accessibility.

C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.

D. Review the manufacturer’s installation instructions and validate that the device is installed in accordance with them.

E. Control Damper Checkout:

1. Verify that control dampers are installed correctly for flow direction.
2. Verify that proper blade alignment, either parallel or opposed, has been provided.
3. Verify that damper frame attachment is properly secured and sealed.
4. Verify that damper actuator and linkage attachment is secure.
5. Verify that actuator wiring is complete, enclosed and connected to correct power source.
6. Verify that damper blade travel is unobstructed.
7. Verify fail position, stroke and range is correct.

F. Control Valve Checkout:

1. Verify that control valves are installed correctly for flow direction.
2. Verify that valve body attachment is properly secured and sealed.
3. Verify that valve actuator and linkage attachment is secure.
4. Verify that actuator wiring is complete, enclosed and connected to correct power source.
5. Verify that valve ball, disc or plug travel is unobstructed.

6. Verify fail position.

7. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.

G. Instrument Checkout:

1. Verify that instrument is correctly installed for location, orientation, direction and operating clearances.

2. Verify that attachment is properly secured and sealed.

3. Verify that conduit connections are properly secured and sealed.

4. Verify that wiring is properly labeled with unique identification, correct type and size and is securely attached to proper terminals.

5. Inspect instrument tag against approved submittal.

6. For flow instruments, verify that recommended upstream and downstream distances have been maintained.

7. For temperature instruments:

   a. Verify sensing element type and proper material.

   b. Verify length and insertion.

3.6. BAS SYSTEM CONTROLLER CHECKOUT

A. Verify power supply.

1. Verify voltage, phase and hertz.

2. Verify that protection from power surges is installed and functioning.

3. Verify that ground fault protection is installed.

4. If applicable, verify if connected to UPS unit.

5. If applicable, verify if connected to a backup power source.

6. If applicable, verify that power conditioning units, transient voltage suppression and high-frequency noise filter units are installed.

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

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

3.7. BAS SYSTEM I/O TESTING, ADJUSTING AND CALIBRATION

A. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.

B. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.

C. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.

D. Equipment and procedures used for calibration shall comply with instrument manufacturer's written instructions.

E. Provide diagnostic and test equipment for calibration and adjustment.

F. Check each instrumentation device by making a comparison between the BAS display and the reading at the device. Record the measured value and displayed value for each device in the BAS Checkout Report.

G. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. An installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.

H. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.

I. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.

J. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

K. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

L. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact making or breaking.
3. Check each digital input point by making a comparison between the BAS display and the state of the sensing device. Record the results for each device in the BAS Checkout Report.

M. Control Dampers:

1. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 50 percent open, to 100 percent closed, to 50 percent closed, and back to 100 percent open.

2. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.

3. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

4. Check each control damper by making a comparison between the BAS display and the position at the device. Record the commanded damper, actual position, and position feedback when applicable for each device in the BAS Checkout Report.

5. If actual damper position doesn't reasonably correspond, replace actuator.

N. Control Valves:

1. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 50 percent open, to 100 percent closed, to 50 percent closed, and back to 100 percent open.

2. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.

3. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

4. Check each control valve by making a comparison between the BAS display and the position at the device. Record the commanded value, actual position, and position feedback when applicable for each device in the BAS Checkout Report.

5. If actual valve position doesn't reasonably correspond, replace actuator.

O. Meters: Check sensors at zero, 50, and 100 percent of Project design values.

P. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

Q. Switches: Calibrate switches to make or break contact at set points indicated.

R. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.

2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistant source.

S. Exercise each binary point.

T. For every I/O point in BAS system, read and record each value at operator workstation, at BAS controller and at field instrument simultaneously. Value displayed at operator workstation, at BAS controller and at field instrument shall match. Report results in BAS Checkout Report.

U. Prepare and submit a BAS Checkout Report documenting results for each I/O point in BAS system and include in each I/O point a description of corrective measures and adjustments made to achieve desire results.

3.8. BAS CONTROLLER I/O CONTROL LOOP TESTS

A. Testing:

1. Test every I/O point connected to BAS controller to verify that safety and operating control set points are as indicated and as required to operate controlled system safely and at optimum performance.

2. Test every I/O point throughout its full operating range.

3. Test every control loop to verify operation is stable and accurate.

4. Adjust control loop proportional, integral and derivative settings to achieve optimum performance while complying with performance requirements indicated. Document testing of each control loop's precision and stability via trend logs.

5. Test and adjust every control loop for proper operation according to sequence of operation.

6. Tune all control loops to obtain the fastest stable response without hunting, offset or overshoot. Record tuning parameters and response test results for each control loop in the BAS Checkout Report. Except from a startup, maximum allowable variance from set point for controlled variables under normal load fluctuations shall be as follows. Within 3 minutes of any upset (for which the system has the capability to respond) in the control loop, tolerances shall be maintained (exceptions noted):

   a. Duct air temperature: Plus or minus 1 deg F.

   b. Space Temperature: Plus or minus 2 deg F.

   c. Chilled Water: Plus or minus 1 deg F.

   d. Hot water temperature: Plus or minus 3 deg F.

   e. Duct pressure: Plus or minus 0.1-inches w.g.

   f. Water pressure: Plus or minus 1 psid.

   g. Duct or space Humidity: Plus or minus 5 percent.

   h. Air flow control: Plus or minus 5 percent of setpoint velocity.

7. Test software and hardware interlocks for proper operation. Correct deficiencies.

8. Operate each analog point at the following:

   a. Upper quarter of range.

   b. Lower quarter of range.

   c. At midpoint of range.

3.9. BAS SYSTEM VALIDATION TESTS

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

B. After approval of Test Plan, execute all tests and procedures indicated in plan.

C. After testing is complete, submit completed test checklist.

D. Pretest Checklist: Submit the following list with items checked off once verified:

1. Detailed explanation for any items that are not completed or verified.
2. Required mechanical installation work is successfully completed and HVAC equipment is working correctly.
3. HVAC equipment motors operate below full-load amperage ratings.
4. Required BAS system components, wiring, and accessories are installed.
5. Installed BAS system architecture matches approved Drawings.
6. Control electric power circuits operate at proper voltage and are free from faults.
7. Required surge protection is installed.
8. BAS system network communications function properly, including uploading and downloading programming changes.
9. Using BACnet protocol analyzer, verify that communications are error free.
10. Each controller's programming is backed up.
11. Equipment, products, tubing, wiring cable, and conduits are properly labeled.
12. All I/O points are programmed into controllers.
13. Testing, adjusting, and balancing work affecting controls is complete.
14. Dampers and actuators zero and span adjustments are set properly.
15. Each control damper and actuator goes to failed position on loss of power.
16. Valves and actuators zero and span adjustments are set properly.
17. Each control valve and actuator goes to failed position on loss of power.
18. Meter, sensor and transmitter readings are accurate and calibrated.
19. Control loops are tuned for smooth and stable operation.
20. View trend data where applicable.
21. Each controller works properly in standalone mode.
22. Safety controls and devices function properly.
23. Interfaces with fire-alarm system function properly.
24. Electrical interlocks function properly.
25. Operator workstations and other interfaces are delivered, all system and database software is installed, and graphic are created.
26. Record Drawings are completed.

E. Test Plan:

1. Prepare and submit a validation test plan including test procedures for performance validation tests.

2. Test plan shall address all specified functions of BAS system and sequences of operation.

3. Explain detailed actions and expected results to demonstrate compliance with requirements indicated.

4. Explain method for simulating necessary conditions of operation used to demonstrate performance.

5. Include a test checklist to be used to check and initial that each test has been successfully completed.

6. Submit test plan documentation 10 business days before start of tests.

F. Validation Test:

1. Verify operating performance of each I/O point in BAS system.

    a. Verify analog I/O points at operating value.

    b. Make adjustments to out-of-tolerance I/O points.

        1) Identify I/O points for future reference.

        2) Simulate abnormal conditions to demonstrate proper function of safety devices.

        3) Replace instruments and controllers that cannot maintain performance indicated after adjustments.

2. Simulate conditions to demonstrate proper sequence of control.

3. Readjust settings to design values and observe ability of BAS system to establish desired conditions.

4. After 24 Hours following Initial Validation Test:

    a. Re-check I/O points that required corrections during initial test.

    b. Identify I/O points that still require additional correction and make corrections necessary to achieve desired results.

5. After 24 Hours of Second Validation Test:

    a. Re-check I/O points that required corrections during second test.

    b. Continue validation testing until I/O point is normal on two consecutive tests.

6. Completely check out, calibrate, and test all connected hardware and software to ensure that BAS system performs according to requirements indicated.

7. After validation testing is complete, prepare and submit a report indicating all I/O points that required correction and how many validation re-tests it took to pass. Identify adjustments made for each test and indicate instruments that were replaced.

G. BAS System Network Bandwidth Test:

1. Test network bandwidth usage on all BAS system networks to demonstrate bandwidth usage under BAS system normal operating conditions.

2. To pass, none of BAS system networks shall use more than 70 percent of available bandwidth under normal operation.

3.10. BAS SYSTEM WIRELESS NETWORK VERIFICATION

A. BAS system Installer shall design wireless BAS system networks to comply with performance requirements indicated.

B. Installer shall verify wireless network performance through field testing and shall document results in a field test report.

C. Testing and verification of all wireless devices shall include, but not be limited to, the following:

1. Speed.

2. Online status.

3. Signal strength.

3.11. FINAL REVIEW

A. Submit written request to Engineer and Construction Manager when BAS system is ready for final review. Written request shall state the following:

1. BAS system has been thoroughly inspected for compliance with contract documents and found to be in full compliance.

2. BAS system has been calibrated, adjusted and tested and found to comply with requirements of operational stability, accuracy, speed and other performance requirements indicated.

3. BAS system monitoring and control of HVAC systems results in operation according to sequences of operation indicated.

4. BAS system is complete and ready for final review.

B. Review by Engineer and Construction Manager shall be made after receipt of written request. A field report shall be issued to document observations and deficiencies.

C. Take prompt action to remedy deficiencies indicated in field report and submit a second written request when all deficiencies have been corrected. Repeat process until no deficiencies are reported.

D. Should more than two reviews be required, BAS system manufacturer and Installer shall compensate entity performing review for total costs, labor and expenses, associated with third and subsequent reviews. Estimated cost of each review shall be submitted and approved by BAS system manufacturer and Installer before making the review.

E. Prepare and submit closeout submittals.

F. BAS system final review shall include a demonstration to parties participating in final review.

1. Coordinate the demonstration 2 weeks in advance with representatives of the Owner, Engineer, Commissioning Agent (if applicable), Construction Manager, Mechanical Contractor, Fire Alarm Contractor and TAB Contractor.

2. Provide staff familiar with BAS system installed to demonstrate operation of BAS system during final review.

3. Provide testing equipment to demonstrate accuracy and other performance requirements of BAS system that is requested by reviewers during final review.

4. Demonstration shall include a detailed review of the control sequences for each system and piece of equipment.

3.12. ADJUSTING

A. Occupancy Adjustments: When requested within 12 months from date of project completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to 2 visits to Project during other-than-normal occupancy hours for this purpose.

3.13. MAINTENANCE SERVICE

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

3.14. SOFTWARE BACK-UPS

A. Upon completion including final adjustments, backup all data to associated NCUs and/or front-end servers/supervisors.

B. Provide two (2) complete back-up electronic Copies of software files for each operator workstation, server, diagnostic terminal unit and equipment controller. The software files shall include all data and software files needed to completely reset or re-install the software for the entire project including a text file with a written description of the reinstall process. Each copy shall be saved to an external hard drive.

1. External Hard Drive: 2 TB, 3.0/2.0 USB, portable hard-drive manufactured by Seagate, Toshiba or Western Digital.

C. All software required to operate, maintain, and program the system becomes the property of the owner.

3.15. SOFTWARE UPDATES

A. At 12-months from the date of completion, update the BAS software to the most recent release. The update(s) shall be scheduled with the Owner and performed under their direct supervision. Verify proper operation after the installation and correct any problems created by the installation process.

1. Software update shall include all labor, licensing and associated fees.

2. If the Owner has an established energy management system serving buildings outside the scope of this project, ensure the software is compatible with the existing system without needing to update it.

3.16. DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls. Training will provide site specific information including but not limited to:

1. As-builts.
2. BAS checkout, startup and calibration report.
3. Controller replacement.
4. Software required to manipulate the system including programming.

END OF SECTION

SECTION 23 90 10 – BAS INSTRUMENTATION

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes instrumentation for building automation systems.

1.2. SUBMITTALS

A. Comply with the requirements of Section 239000.

B. Product Submittals: Provide data for product indicating compliance with the requirements of this project.

C. Close-Out Submittals:

1. Operation and Maintenance Data: For instrumentation to include in operation and maintenance manuals.

1.3. QUALITY ASSURANCE

A. Comply with BAS general requirements in Section 239000.

1.4. COORDINATION

A. Coordinate location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation. Verify all locations with Engineer prior to installation.

B. Coordinate sources of 120V power with the Electrical Contractor and Owner for control devices. Extend power from sources as needed.

1.5. WARRANTY

A. Warranty: Provide one-year manufacturer’s parts and labor warranty for each energy and flow meter.

1. Electronic Actuators: Parts and labor for 5 years from the date of completion.

1.6. EXTRA MATERIALS

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. Replacement Materials: One replacement diaphragm or relay mechanism for each unique valve motor, controller, thermostat, humidistat and positioning relay.

PART 2 - PRODUCTS

2.1. SENSORS

A. Provide sensors as indicated in control diagrams and sequences of operation or as needed to perform the intended operations.

B. Sensors shall be vibration and corrosion resistant and designed for the intended use.

C. Provide explosion proof sensors suitable for Class 1, Division 1 or Division 2 hazardous classified areas.

2.2. TEMPERATURE SENSORS, STANDARD ACCURACY

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

1. Automation Components Inc. (ACI)
2. Building Automation Products Inc. (BAPI)
3. Distech
4. Honeywell
5. Johnson Controls Inc. (JCI)
6. Siemens

B. Description: Temperature sensor shall be thermistor or resistance temperature detector (RTD) type and compatible with BAS.

1. Accuracy: Plus or minus 0.5 deg F over 32 to 158 deg F range.
2. Operating Temperature: Minus 40 to 300 deg F.

C. Wall-Mounted Temperature Sensor: Sensors in white plastic enclosure with insulated backing.

1. LED display.
2. Set point adjustment.
3. Push button occupancy override switch.

D. Wall-Mounted Flat-Plate Temperature Sensor: Stainless steel, flat plate sensor that fits in a standard 2-inch by 4-inch junction box with tamperproof screws. Provide with insulated backing.

E. Outside Air Temperature (OAT) Sensor: Thermistor or RTD compatible with BMS installed in wall-mounted weatherproof enclosure with conduit entrance and aluminum LB with PVC sun and windscreen.

F. Duct-Mounted Single-Point Temperature Sensor: Rigid sensor sealed in 0.25-inch stainless steel probe of length between one-third and two-thirds of the duct width in duct-mounted metal housing with conduit entrance.

1. Single-point may be used in ducts where there is no air stratification possibilities. Sensor shall be mounted downstream to allow for sufficient mixing.

G. Duct-Mounted Averaging Element Temperature Sensor: Multi-point sensor, contained in a flexible copper or woven continuous metallic sheath, with length sized for duct.

1. Provide a minimum of 1 foot of sensing element for every 3 square-feet of duct/coil area. Multiple averaging elements may be required.

2. Averaging elements shall be used where ducts are prone to stratification, and downstream of heating/cooling coils.

3. Where multiple sensors are provided, sensors may be wired in a series-series, parallel-parallel pattern (requires four or nine sensors) in lieu of multiple inputs.

4. Plenum rated sheaths are not acceptable.

H. Thermowell-Mounted Immersion Temperature Sensor: Rigid sensor sealed in 0.25-inch stainless steel probe with 3-part moisture protection system and minimum length equal to 20-percent of pipe width. Provide machined, single-piece brass or stainless steel thermowell compatible with sensor housing.

I. Strap-On Piping Aquastat Temperature Sensor: Snap acting SPDT, pipe mount, automatic or manual reset switch (as indicated on drawings) that trips if temperature sensed is equal to or above setpoint. Sensing range appropriate for application.

2.3. TEMPERATURE SENSORS, HIGH ACCURACY

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

1. Vaisala (wall-mounted TMW series / duct-mounted TMD series).

B. Description: Temperature sensor shall be thermistor or resistance temperature detector (RTD) type, compatible with BAS and meet the requirements of standard accuracy temperature sensors except for more stringent requirements below. Sensor shall be provided with NIST traceable calibration certificate.

1. Accuracy:

   a. Wall-Mounted: Plus or minus 0.36 deg F at 70 deg F.

   b. Duct-Mounted: Plus or minus 0.18 deg F at 70 deg F.

2. Measurement Range:

   a. Wall-Mounted: Minus 23 to plus 130 deg F.

   b. Duct-Mounted: Minus 40 to plus 175 deg F.

2.4. THERMOSTATS

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

1. Automation Components Inc. (ACI)

2. Honeywell

3. Johnson Controls Inc. (JCI)

4. Schneider Electric

B. Digital Stand-Alone Thermostat: Electric, solid-state, microcomputer-based room thermostat.

1. Automatic switching from heating to cooling.

2. Preferential rate control to minimize overshoot and deviation from set point.

3. Set up for four separate temperatures per day, with individual programming for each day of the week (4 programs per day, 7 days per week, 28 potential programs).

4. Instant override of set point for continuous or timed period from 1 hour to 31 days.

5. Short-cycle protection.

6. Selection features include degree F or degree C display, 12- or 24-hour clock, keyboard disable and fan on-auto.

7. Powered off unit 24Vac transformer, with solid-state memory in which programming is retained on power failure. Battery acceptable only for time and date upkeep during power failure.

8. Thermostat display features include the following: time of day, actual room temperature, programmed temperature, programmed time, duration of timed override, day of week, and system mode indications include "HEATING", "OFF", "FAN AUTO" and "FAN OFF".

9. Combination Thermostat, Humidistat, Carbon Dioxide, and/or Occupancy Sensor: Where there is a requirement for a thermostat with humidistat, carbon dioxide, and/or occupancy sensing functions at the same location, provide combination unit. The individual sensors must each meet the specifications details herein.

10. Provide remote sensing element (electronic sensor) as required for application.

C. Line-Voltage Stand-Alone Combination Thermostat and Fan Switch: Line-voltage thermostat with push-button or lever-operated fan switch.

1. Label switches "FAN ON-OFF", "FAN HIGH-LOW-OFF" or "FAN HIGH-MED-LOW-OFF" as applicable.

2. Mount on single electric switch box.

D. Line-Voltage Stand-Alone On-Off Thermostats: Bimetal-actuated, open contact or bellows-actuated, enclosed, snap-switch or equivalent solid-state type, with heat anticipator; listed for electrical rating; with concealed set-point adjustment, 55 to 85 deg F set-point range, and 2 deg F maximum differential.

1. Electric Heating Thermostats: Equip with off position on dial wired to break ungrounded conductors.

2. Selector Switch: Integral, manual on-off-auto.

E. Low-Voltage Stand-Alone On-Off Thermostats: NEMA DC 3, 24-V, bimetal-operated, mercury-free, with adjustable or fixed anticipation heater, concealed set-point adjustment, 55 to 85 deg F set-point range, and 2 deg F maximum differential.

F. Electric Low-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual automatic reset switch that trips if temperature sensed across any 12 inches of bulb length is equal to or below set point.

1. Bulb Length: Minimum 20 feet.

2. Quantity: One thermostat for every 20 sqft. of coil surface.

G. Electric High-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual automatic reset switch that trips if temperature sensed across any 12 inches of bulb length is equal to or above set point.

1. Bulb Length: Minimum 20 feet.

2. Quantity: One thermostat for every 20 sqft. of coil surface.

2.5. HUMIDITY SENSORS, STANDARD ACCURACY

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

1. Automation Components Inc. (ACI)

2. Building Automation Products Inc. (BAPI)

3. Distech

4. Honeywell

5. Johnson Controls Inc. (JCI)

6. Siemens

B. Description: Laser-trimmed thermoset polymer-based capacitive-type sensor, 4-20mA or 0-10Vdc output proportional to relative humidity range of 0% to 100% and compatible with 24 Vac/dc power supply and BAS.

1. Accuracy: Plus or minus 3-percent over 10 to 90-percent range.

2. Measurement Range: 0 to 100-percent.

3. Operating Temperature: Minus 40 to 140 deg F.

C. Wall-Mounted Relative Humidity Sensor: Sensors in white plastic enclosure with insulated backing.

D. Outside Air Relative Humidity (OAH) Sensor: Sensor installed in wall-mounted weatherproof enclosure with conduit entrance and aluminum LB with PVC sun and windscreen.

E. Duct-Mounted Relative Humidity Sensor: Sensor with 9-inch long probe in duct-mounted plenum-rated housing with conduit entrance.

2.6. HUMIDITY SENSORS, HIGH ACCURACY

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

1. Vaisala (wall-mounted HMW series / duct-mounted HMD series).

B. Description: Humidity sensor shall be compatible with BAS and meet the requirements of standard accuracy humidity sensors except for more stringent requirements below. Sensor shall be provided with NIST traceable calibration certificate.

1. Accuracy:

   a. Wall-Mounted: Plus or minus 1.7 percent over 0 to 90 percent range and plus or minus 2.5 percent over 90 to 100 percent range.

   b. Duct-Mounted: Plus or minus 1.5 percent over 0 to 90 percent range and plus or minus 2.5 percent over 90 to 100 percent range.

2. Measurement Range: 0 to 100 percent.

3. Operating Temperature: Minus 40 to plus 140 deg F.

C. Sensor shall have the ability to be calibrated without disturbing operation using a single-point field calibrator.

2.7. COMBINATION SENSORS

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

1. Automation Components Inc. (ACI)
2. Building Automation Products Inc. (BAPI)
3. Distech
4. Honeywell
5. Johnson Controls Inc. (JCI)
6. Siemens
7. Vaisala

B. Combination Wall-Mounted Temperature and Humidity Sensors: Sensors in white plastic enclosure with insulated backing.

1. Where monitoring temperature and relative humidity are required at the same location, provide combination relative humidity and temperature sensors. Individual sensors must meet each of the specification details herein.

2. Where required, combination relative and humidity sensors shall have the ability to output additional parameters including dew point, enthalpy and wet bulb temperature.

3. LED display.

4. Set point adjustment.

5. Push button occupancy override switch.

C. Combination Wall-Mounted Sensor Modules: Sensors which measure multiple conditions as noted such as temperature, relative humidity, pressure, etc. in white plastic enclosure with insulated backing.

1. Where monitoring multiple conditions are required at the same location, provide combination sensor modules. Individual sensors must meet each of the specifications details herein.

a. Where carbon dioxide is provided beside temperature and/or humidity sensors, it shall be provided separately and not combined into a single sensor.

2. Where required, combination sensor modules shall have the ability to output additional parameters including dew point, enthalpy and wet bulb temperature.

3. LED display.

4. Set point adjustment.

5. Push button occupancy override switch.

D. Combination Duct-Mounted Temperature and Humidity Sensors:

1. Where monitoring temperature and relative humidity are required at the same location, provide combination relative humidity and temperature sensors. Individual sensors must meet each of the specification details herein.

2. Where required, combination relative and humidity sensors shall have the ability to output additional parameters including dew point, enthalpy and wet bulb temperature.

2.8. DRY (AIR) PRESSURE SENSORS, STANDARD ACCURACY

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

1. Automation Components Inc. (ACI)

2. Honeywell

3. Setra

4. Veris

B. General Requirements: Diaphragm pressure transducer and amplifier type sensor, 4-20mA or 0-10Vdc output proportional to pressure range and compatible with 24 Vac/dc power supply and BAS. Each sensor shall have a local display.

1. Accuracy: Plus or minus 1-percent of full scale output range.

2. Operating Temperature Range: -4 to 140 deg F.

3. Burst Pressure: 5 psid.

C. Duct-Mounted Static Pressure Sensors:

1. Uni-directional.

2. Measurement Range: 0 to 6 inches wg for low and medium pressure applications and higher as required for high pressure applications.

D. Room Pressure Sensors:

1. Bi-directional.

2. Measurement Range: Minus 0.2 to positive 0.2 inches wg.

E. Building Pressure Sensors:

1. Bi-directional.

2. Measurement Range: Minus 0.2 to positive 0.2 inches wg.

3. Provide outside air reference kit (Dwyer A-306 or equivalent) with tubing, mounting bracket and required hardware.

F. Air Filter / Coil Differential Pressure Sensors:

1. Uni-directional.

2. Measurement Range: 0 to 2-inches wg and higher as required.

2.9. DRY (AIR) PRESSURE SENSORS, HIGH ACCURACY

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

1. Phoenix Controls

2. Setra

B. General Requirements: All requirements of standard accuracy dry pressure sensors are applicable, except where more stringent requirements below. Sensor shall be provided with NIST traceable calibration certificate.

1. Accuracy: Plus or minus 0.5-percent of full scale output range.

2. Operating Temperature Range: -4 to 140 deg F.

3. Burst Pressure: 5 psid.

2.10. DRY (AIR) PRESSURE SWITCHES

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

1. Cleveland Controls

2. Dwyer

B. General Requirements: Diaphragm pressure switch with SPDT contacts and setpoint adjustment knob. Sensor shall be uni-directional and be manual or automatic reset in accordance with drawings.

1. Accuracy: Plus or minus 2 percent of full scale output.
2. Measurement Range: 0 to 0.25-inches wg for building and duct pressurization applications; 0 to 1.50-inches wg for filter alarms; and 0 to 12-inches wg for high static alarms.
    a. Status Inputs for Fans: Adjustable range of 0 to 6-inches wg.
3. Operating Temperature Range: -4 to 185 deg F.

C. “Paddle-style” air flow switches are not allowed. Use dry pressure switch in lieu of paddle.

2.11. DRY (AIR) FLOW SWITCHES

A. Manufacturers: Subject to compliance with requirements, provide products by the following or approved equivalent:
1. McDonnell & Miller

B. General Requirements: Explosion proof air flow paddle SPDT switch suitable for Class 1, Division 1 or Division 2 hazardous classified areas.

C. Ambient temperature 120 deg F max, media temperature 275 deg F max.

D. Select switches for appropriate flow and velocity ranges.

E. Provide intrinsic safety barriers, wiring, and seals.

2.12. WET (WATER / STEAM) PRESSURE SENSORS

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

B. General Requirements: Diaphragm pressure transducer and amplifier type sensor, 4-20mA or 0-10Vdc output proportional to pressure range and compatible with 24 Vac/dc power supply and BAS. Sensors shall have stainless steel wetted components in a weatherproof wiring housing. Each sensor shall have a local display. Sensors shall be uni-directional for one-way flow or bi-directional for reversing flow.
1. Accuracy: Plus or minus 0.25 percent of full scale output range.
2. Proof Pressure: Two times rated input pressure or greater.
3. Burst Pressure: Five times rated input pressure or greater.

C. Water Pressure Sensors:
1. Measurement Range: 0 to two times the set point or anticipated pressure.
2. Operating Temperature Range: 0 to 175 deg F.

D. Steam Pressure Sensors:

1. Measurement Range: 0 to two times the set point or anticipated pressure.

2. Operating Temperature Range: 0 to 450 deg F.

E. Water Differential Pressure Sensors:

1. Measurement Range: 0 to two times the set point or anticipated pressure.

2. Operating Temperature Range: 0 to 175 deg F.

3. Provide with four or five valve manifold. Sensors shall be factory-connected to manifold.

F. Cabled Water Differential Pressure Sensors:

1. Measurement Range: 0 to two times the set point or anticipated pressure.

2. Operating Temperature Range: 0 to 175 deg F.

3. Provide with sufficient cable length to mount sensor at eye level.

2.13. WET (WATER) PRESSURE SWITCHES

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

1. Cleveland Controls

2. Dwyer

B. General Requirements: Diaphragm pressure switch with SPDT contacts and setpoint adjustment knob. Sensor shall be uni-directional and be manual or automatic reset in accordance with drawings.

1. Accuracy: Plus or minus 2 percent of full scale output.

2. Measurement Range: 0 to 2 times the set point or anticipated pressure.

   a. Status Inputs for Pumps: Adjustable range of 8 to 60 psig, piped across pump.

3. Operating Temperature Range: -20 to 200 deg F.

C. “Paddle-style” water flow switches are not allowed. Use wet pressure switch in lieu of paddle.

2.14. CARBON DIOXIDE (CO_2) SENSORS

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

1. Honeywell

2. Veris

3. Vaisala

B. General Requirements: Non-dispersion infrared (NDIR) type sensor, 4-20mA or 0-10Vdc output proportional to carbon dioxide (CO_2) range and compatible with 24 Vac/dc power supply and BAS. Sensor shall have local display.

1. Accuracy: Plus or minus 2 percent of reading or 30 ppm, whichever higher.

2. Measurement Range: 0 to 2000 ppm.

3. Operating Temperature Range: 32 to 120 deg F.

4. Standard Calibration: No maintenance or periodic sensor replacement needed. The sensor shall have a 5-year calibration interval, utilizing an automatic unoccupied period calibration.

5. Where the building operates 24 hours per day (no unoccupied periods), sensors capable of maintaining accuracy without the automatic unoccupied period calibration sequence will be installed.

C. Wall-Mount Carbon Dioxide Sensors: Sensors with plastic enclosure that fits on a standard 2-inch by 4-inch junction box.

D. Duct-Mount Carbon Dioxide Sensors: Sensors with sampling tube and duct-mounted metal housing with conduit entrance.

2.15. INDOOR AIR QUALITY SENSORS

A. Air Quality Sensors: Sensors that measure the volatile organic compounds (VOC) including: methane, ethylene, hydrogen, carbon monoxide (CO), propane and ammonia.

1. Wall-Mounted Air Quality Sensors: Microprocessor based using a semiconductor element based on the Taguchi gas principle with 4-20 Ma or 0-10 Vdc output and a 24 Vac/dc power supply in white plastic enclosure. Programming and selection via internal push buttons and jumpers.

   a. Temperature: 32 to 120 deg F.

2. Duct-Mounted Air Quality Sensors: Microprocessor based using a semiconductor element based on the Taguchi gas principle with 8-inch duct probe, 4-20 Ma or 0-10 Vdc output and a 24 Vac/dc power supply in white plastic enclosure. Programming and selection via internal push buttons and jumpers.

   a. Temperature: 32 to 120 deg F.

B. Carbon Monoxide (CO) Sensors: Electrochemical type sensor with 4-20Ma or 0-10 Vdc output of Carbon Monoxide sensed compatible with BAS system. Unit shall be complete with 85 Db audible alarm and have visual output reading via an LCD display of the gas sensed. Provide two (2) relay contacts, at minimum, per sensor, to indicate CO warning level (initially set at 50ppm) and CO alarm level (initially set at 100ppm) for each sensing point. The proposed sensor locations shall be submitted at the shop drawing stage and shall be amended as directed by the Owner and/or Engineer.

1. Range: 5 percent accuracy from 0 to 300 ppm.

2. Temperature: 32 to 120 deg F.

3. Calibration: Factory calibrated and only requires calibration after a minimum one (1) year service.

C. Oxygen Sensors: Solid-state zircon cell sensor with 4 to 20 Ma output.

1. Accuracy: 5 percent of reading.

2. Temperature: 32 to 120 deg F.

2.16. INDOOR AIR QUALITY SENSORS FOR HAZARDOUS CLASSIFIED AREAS

A. Manufacturers: Subject to compliance with requirements, provide products by the following or approved equivalent:

1. Sensidyne Industrial Health and Safety Instrumentation.

B. Air Quality Sensors: Class I Division 1 sensors that measure combustibles, flammables, toxics, corrosives, oxygen enrichment, and oxygen deficiency. Intrinsically safe sensor head, field replaceable without declassification or work permits, remote sensor mount up to 100 feet away.

1. Gas Sensors: Electrochemical, Infrared, Poison Resistant Catalytic Bead.

2. Electrical:

a. Power requirement: 24 VDC with relay card on combustible sensors.

b. Output: 4-20mA, one (1) SPDT configurable relay, optional card with three (3) SPDT configurable relays.

c. Communications: 4-20 mA, RS-485 Modbus

d. Interface: Menu driven, password protected, LEDs and graphic LCD.

3. Transmitter Environmental:

a. Temperature: -20 to 158 deg F.

b. Humidity: 0-90% RH, non-condensing for indoor and outdoor locations.

c. Moisture resistance with rainshield.

4. Enclosure: Blue cast aluminum

5. Accessories: Sensor shield, flow block, calibration adaptor, sampling tubing as recommended by manufacturer for compatibility, necessary mounting and installation hardware, and intrinsic safety barriers, wiring, and seals.

C. Sample Draw System: FM listed for NFPA 820 compliance. Sample air is pumped or aspirated to the sample draw system from a Class I Division 1 area with sample draw system located in a Class I Division 2 area. Flow sensor with fail safe relay, internal power switch and flow adjustment, external flow indication and LED’s, and 24 VDC power source for gas detectors.

1. Controls and Display:

a. External: Flow meter, green power LED and red fault / low flow LED.

b. Internal: On-off switch, voltage out adjust, and flow rate adjust.

c. Outputs: Two 24 VDC power terminals, SPDT fault / low flow relay contact.

2. Environmental:

a. Temperature: -4 to 104 deg F.

b. Humidity: 5-95% RH, non-condensing for indoor and outdoor locations.

3. Enclosure: NEMA 3R Fiberglass wall mount with conduit entries.

4. Pump: Diaphragm type rated at 1.0 LPM at 40 inches H_2O at pressurized leak rate of less than 1.0 inch H_2O drop in 5 seconds at 25 inches H_2O.

5. Wetted Parts: Polycarbonate, Neoprene, Tygon 2075, Silicone Silastic, 304/316 stainless steel, Buna-N, Brass, PVC, Glass, Acrylic and user tubing.

6. Accessories: Coalescing Filter / drain, sampling tubing as recommended by manufacturer for compatibility, necessary mounting and installation hardware, and intrinsic safety barriers, wiring, and seals.

D. Local Alarm Annunciators: Single and dual strobes with annunciators, power supply option as power source for gas detectors, approved for general purpose and Class I Division 2 hazardous areas.

2.17. RELAYS

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

1. Functional Devices

2. IDEC

3. Veris

B. General Requirements: Relays shall be electrically rated for each application, minimally SPDT with 10A (resistive) contacts, and plenum rated. They shall include LED indicator light and hand-off-auto (HOA) unless otherwise specified. Relays shall be UL-listed and mounted in NEMA 1 enclosure for indoor applications and NEMA 4 for outdoor.

C. BAS Panel-Mounted Relays: Socket (“ice-cube”) style with mounting base and replaceable relay. Relays in panel will be screw terminal terminations; relays with wiring whip from factory are not allowed for panel mounting. HOA not required if controller has internal HOA or output being controlled has HOA (i.e. VFD).

D. Nipple-Mounted Relays: Enclosed relay compatible with conduit knockout. Acceptable for field use. With or without factory-provided wiring whip. HOA not required if output being controlled has HOA (i.e. VFD).

E. Track-Mounted Relays: Acceptable for use in terminal unit control panels. Screw terminal terminations. Track-mounted relays are not to be installed in field unless inside an equipment control panel (no track-mounted relays in electrical boxes). HOA not required if output being controlled has HOA (i.e. VFD).

F. Combination Motor Starter / Current Switch Relays: Allowed only for single-phase equipment and must be mounted such that pilot light is exposed (combination motor starter / current switch relays which install inside of motor starter/VFDs are not allowed). Relay and current switch must each meet the specifications details herein. HOA not required if output being controlled has HOA (i.e. VFD).

2.18. CURRENT SENSORS, SWITCHES AND TRANSFORMERS

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

1. Automation Components Inc. (ACI)
2. Setra
3. Veris

B. General Requirements: Devices shall be rated for their associated motor load and voltage, have input and output isolation and have LED indication of status. Devices shall be selected based on application including but not limited to standard 60 hertz motors, variable speed controllers or electronically communicated motors (ECM's). Devices shall be UL-listed and mounted in NEMA 1 enclosure for indoor applications and NEMA 4 for outdoor.

1. Accuracy: 2 percent of full-scale output.
2. Measurement Range: 0 to 2 times the anticipated current.
3. Operating Temperature Range: Minus 30 to plus 140 deg F.

C. Current Status Switch: Self-powered current switch with normally open (NO) contacts for Go/No Go or On/Off status. Provide with adjustable trip point where applicable.

D. Current Sensor / Transducer: Sensor with 4-20 mA or 0-10Vdc output proportional to current draw.

E. Control Transformers: Transformer with 4-20 mA or 0-10Vdc output proportional to current draw.

2.19. DETECTION EQUIPMENT

A. Water Leak Detection Alarm: Adjustable-height multi-point water detection sensor constructed to be corrosion and abrasion resistant and configured for normally open or normally closed as required by the application with 24Vac/dc power supply. Provide remote-mounted sensing probe and cable as needed for each application. Dwyer (WD series) or equal.

1. Temperature: Minus 40 to positive 185 deg F.

B. Condensate Drain Pan Overflow Safety Switch: Low-voltage, float-type safety switch designed for condensate drain pan high-level alarm for unit shutdown and alarming. Little Giant Pump/Franklin Electric (ACS series) or equal.

C. Occupancy Override Switch: Low-voltage wall switch in a standard single-switch back box with momentary switch, green LED "on" indicator light, with white plastic faceplate. Hubbell (LVSM series) or equal.

D. Occupancy Sensor: Dual-technology passive infrared (PIR) and ultrasonic occupancy sensor with adjustable time delay of 5 to 45 minutes, daylight sensor lockout, sensitivity control, and 180-degree field of view with vertical sensing adjustment; for flush wall or ceiling mounting in standard metal outlet box. Provide sensor with LED light to indicate when motion is being detected during test and normal operation. Provide sensor with auxiliary dry contacts. Power supply to the sensor shall be 24Vdc, located within the outlet box and be plenum-rated.

1. Ceiling-Mounted Sensors: Cooper Lighting/Eaton (MicroSet Series), Hubbell (OMNI Series), Leviton (OSC Series), Lutron (LOS C Series) or Watt Stopper (LMDC Series).

2. Wall-Mounted Sensors: Hubbell (LightHAWK2 Series), Lutron (Maestro Series), Watt Stopper (LMDW Series).

2.20. STATUS SENSORS

A. Shaft-Mounted Limit Switches: SPDT/DPDT mercury-free, gravity-actuated mechanical switch with adjustable shaft connection.

B. Whisker Limit Switches: SPDT/DPDT mechanical whisker switch with adjustable trim arm.

2.21. MANUAL OVERRIDE DEVICES

A. Emergency Stop Buttons: ADA-compliant, red emergency pushbutton in white polycarbonate plastic enclosure with clear flip-up cover and stainless steel backplate. Button shall be reset by twisting or pulling out the button; a procedure that requires disassembly or a key is not acceptable. 120V or 24 V as needed. Provide label with indication of operation. Safety Technology International (STI) (Stopper Station series) or approved equal.

2.22. TRANSFORMERS AND CONTACTORS

A. Control Transformers: Class 2, sized and rated for application. Circuit breaker overcurrent protection; fused or internal overcurrent protection is not allowed. Transformers shall be sized so that connected load does not exceed 75 percent of rating. Functional Devices TR series or equal.

B. Power Contactors: NEMA ICS 2 AC general purpose magnetic contactor mounted in NEMA 1 enclosure for indoor locations and NEMA 4 for outdoor.

2.23. POWER MONITORING DEVICES

A. Voltage Transmitter (100 to 600 V ac): Comply with ISA 50.00.01, single-loop, self-powered transmitter, adjustable, with suitable range and 1 percent full-scale accuracy.

B. Power Monitor: 3-phase type with disconnect/shorting switch assembly, listed voltage and current transformers, with pulse kilowatt hour output and 4- to 20-mA kW output, with maximum 2 percent error at 1.0 power factor and 2.5 percent error at 0.5 power factor.

2.24. ANNUNCIATION DEVICES

A. Visible Status / Alarm Devices: UL-listed; two color LED lights, with green and red polycarbonate lens and white ABS plastic enclosure, wall-mounted on an aluminum faceplate. Words, for example "Fume Hood (Number) Fan Status", shall be printed in minimum 1/2-inch high letters on the enclosure. Each light shall be steady or flashing as noted. 120V or 24 V as needed. Rockwell Automation (855W series) or approved equal.

2.25. ELECTRONIC ACTUATORS

A. Manufacturers: All valve actuators shall be supplied from a single manufacturer. All damper actuators shall be supplied from a single manufacturer. Provide actuators manufactured by one of the following:

1. Belimo
2. Honeywell
3. Johnson Controls Inc. (JCI)
4. Schneider Electric (TAC Dura-Drive)
5. Siemens

B. General Requirements: Direct-coupled type, motor-operated, electric and electronic actuators designed for minimum 60,000 full-stroke cycles at rated torque.

1. Voltage: 24Vac unless otherwise specified. 120V actuators may be allowed if coordinated by controls contractor with electrical contractor to provide local disconnect and power. Circuit must be fed from the same power panel as the equipment or control panel and a spare circuit must be available.
2. Power: Contractor is responsible for sizing control transformers based on the VA of the actuator(s) selected. Provide electronic overload protection throughout the entire operating range in both directions.
3. Coupling: V-bolt and V-shaped, toothed cradle. Bolt and set screw method of attachment is unacceptable.
4. Fail-Safe: Where indicated, provide actuator to fail via a mechanical spring return mechanism, to drive controlled device to an end position (open or close) on loss of power. Electronic fail-safe is not allowed, unless specifically reviewed and accepted by Engineer. Provide external, manual gear release on non-spring-return actuators.
5. Temperature Rating:
    a. Standard Dampers and Valves: Minus 22 to plus 122 deg F.
    b. Smoke Dampers: Minus 22 to plus 250 deg F.
6. Housing: Minimum NEMA Type 2, mounted in any orientation, for indoor locations and NEMA Type 3R, mounted in any orientation, for outdoor locations.
7. Stroke Time:
    a. Normal: 120 seconds or less from fully closed to fully open, or fully open to fully closed.
    b. Fast-Acting: 12 seconds open, 5 seconds closed unless otherwise noted.
8. Actuators shall operate related valve(s)/damper(s) with sufficient reserve power to provide smooth modulating action or two-position action and proper speed of response at velocity and pressure conditions to which the valve/damper is subjected.

9. Actuators shall produce sufficient power and torque to close off against the maximum system pressures encountered. Actuators shall be sized to close off against the designed pump/fan shutoff pressure as a minimum requirement.

10. Select actuators to fail in desired position in the event of a power failure. See drawings for power failure modes.

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

12. Actuators shall be capable of being mechanically and electrically paralleled to increase torque if required.

13. Provide actuator enclosure with a heater and controller where required by application.

14. Comply with requirements in Section 230513.

C. Two-Position Actuators: Single direction, spring return or reversing (non-spring return) type.

D. Modulating Actuators:

1. Capable of stopping at all points across full range and starting in either direction from any point in range.

2. Control Input Signal:

   a. Three Point, Tristate, or Floating Point: Clockwise and counter-clockwise inputs. One input drives actuator to open position, and other input drives actuator to close position. No signal of either input, the actuator remains in the last position.

   b. Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for zero to 5-, zero- to 10-, 1 to 5- or 2- to 10-Vdc and 4- to 20-mA signals.

3. True Proportional Analog Signals: The following space types shall use true proportional analog signals which do not require periodic re-initialization. Verify exact spaces with Engineer.

   a. Hospitals: Operating, delivery, procedure, imaging, decontamination and sterile processing, isolation, pharmacies, laser eye, catheterization labs, cystoscopic, trauma, triage, radiology waiting, emergency department waiting, emergency department decontamination, autopsy, bronchoscopy, endoscope cleaning, and lab rooms.

   b. Laboratories and support spaces.

4. Floating Control: Floating control actuators shall be allowed only for damper and valve control for room terminal units where there is not a room pressurization requirement. Use of floating controls must be specifically requested by the contractor for specific spaces and reviewed by the engineer. Submission of floating control actuators without specific comment by the contractor for spaces and the resulting review by the Engineer does not constitute approval for use.

5. Pulse width modulation (PWM), or any other analog signal that is not specified above is not allowed.

E. Position Feedback: Where indicated, equip two-position actuators with auxiliary switches (SPDT) for remote monitoring of open and/or closed position. Point of open and/or closed position can be adjusted over the actuators range of operation (0-100%). Where indicated, equip modulating actuators with a position feedback through current and/or voltage signal for remote monitoring.

F. Run Time:

1. Normal: 120 seconds from closed to open or open to closed.

2. Fast-Acting: 12 seconds closed to open and 5 seconds open to closed unless otherwise noted.

a. Smoke Control System Components

b. Emergency System Components

c. Fuel Shut-Off Valves

2.26. HYDRONIC CONTROL VALVES

A. General Requirements: Factory fabricated of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated. Refer to Section 232119 for general information about valve construction and installation. Provide stainless steel internal components.

1. Control valves assemblies shall be provided and delivered from a single manufacturer as a complete assembly, with the actuator installed at the factory.

2. Control valves shall be two- or three-way as specified on the drawings.

3. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system (pump) head for two and three-way valves but not less than 40 psig.

4. Provide with extended neck as required to accommodate insulation thicknesses as specified. Reference 230719 for insulation requirements.

B. Pressure-Independent Control Valves (PICV):

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

a. Belimo (PIQCV series up to 3/4-inch and ePIV series for 1-inch and larger)

b. Bell & Gossett (Ultra Setter series)

c. Danfoss (AB-QM series)

d. Flow Control Industries, Inc. (Delta P series)

e. Griswold (MVP series)

f. Johnson Controls (PI-1000 series)

g. Siemens (599 series)

2. Construction:

   a. Mechanical pressure regulation style PIC valves shall have factory installed pressure/temperature test ports (Pete's Plugs) across the pressure regulator at the factory.

   b. Pressure independent control valves 1-inch NPS or larger may use ultrasonic flow measurement. The ultrasonic flow meter will meet the specifications herein.

3. Sizing:

   a. Valve shall be sized for full port at pipe line size for the GPM specified of the device.

   b. Operating Differential Pressure Range: 5 to 50 PSID or better.

   c. The flow through the valve shall not vary more than +/- 5% due to system pressure fluctuations across the valve in the selected operating range. The control valves shall accurately control the flow from 0 to 100% full rated flow.

C. Pressure-Dependent Ball-Style Control Valves:

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

   a. Belimo (CCV Series)

   b. Griswold (Unimizer Series)

   c. Honeywell (VB Series)

   d. Johnson Controls (VG1000 Series)

   e. Schneider Electric (VBB/VBS Series)

   f. Siemens

2. Flow Characteristics: Two-way valves shall have equal percentage characteristics. Three-way valves shall have equal percentage characteristics on A-Port and linear characteristics for B-Port. Bypass applications shall have linear percentage characteristics.

3. Sizing:

   a. Two Position (Open/Closed): Line size or size using a 1 psig pressure differential.

   b. Two-Way Modulating: Size between 2 and 5 psig pressure differential.

   c. Three-Way Modulating: Size between 2 and 5 psig pressure differential.

   d. Effective Cv: For any valve smaller than line size, the pressure drop due to the reduction in pipe size shall be taken into effect.

D. Pressure-Dependent Globe-Style Control Valves:

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

a. Belimo

b. Griswold

c. Honeywell

d. Johnson Controls Inc. (JCI)

e. Schneider Electric

f. Siemens

2. Flow Characteristics: Two-way valves shall have equal percentage characteristics. Three-way valves shall have equal percentage characteristics on A-Port and linear characteristics for B-Port. Bypass applications shall have linear percentage characteristics.

3. Sizing:

a. Two Position (Open/Closed): Line size or size using a 1 psig pressure differential.

b. Two-Way Modulating: Size between 2 and 5 psig pressure differential.

c. Three-Way Modulating: Size between 2 and 5 psig pressure differential.

d. Effective Cv: For any valve smaller than line size, the pressure drop due to the reduction in pipe size shall be taken into effect.

E. Pressure-Dependent Butterfly-Style Control Valves:

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

a. Belimo (HD Series)

b. Honeywell (VFF Series)

c. Johnson Controls (VF Series)

d. Schneider Electric (VF Series)

e. Siemens (BV Series)

2. Sizing:

a. Two Position (Open/Closed): Line size or size using a 1 psig pressure differential.

b. Two-Way Modulating: Size between 2 and 5 psig pressure differential. Size for the design flow with the disc at 60-degree open position and the design velocity less than 12 FPS.

F. Pressure-Dependent High-Performance Butterfly-Style Control Valves:

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

a. Bray (McCannalok MK series)

b. DeZurick (BHP series)

c. Flowserve (Valtek Valdisk series)

d. Neles / Jamesbury (Easyflow series)

2. Sizing:

a. Two Position (Open/Closed): Line size or size using a 1 psig pressure differential.

b. Two-Way Modulating: Size between 2 and 5 psig pressure differential. Size for the design flow with the disc at 60-degree open position and the design velocity less than 12 FPS.

2.27. STEAM CONTROL VALVES

A. General Requirements: Factory fabricated of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated. Refer to Section 232213 for general information about valve construction and installation. Provide stainless steel internal components.

1. Control valves assemblies shall be provided and delivered from a single manufacturer as a complete assembly, with the actuator installed at the factory.

2. Working Temperatures:

a. Less than 15 psig: 250 deg F.

b. 15 psig to 150 psig: 366 deg F.

3. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of operating inlet design pressure.

4. Provide with extended neck as required to accommodate insulation thicknesses as specified. Reference 230719 for insulation requirements.

B. Globe-Style Control Valves:

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

a. Armstrong

b. Johnson Controls Inc. (JCI)

c. Schneider Electric

d. Spirax-Sarco

2. Flow Characteristics: Linear or equal percentage characteristics.

3. Sizing:

a. Two Position: Line size or size using 10 percent of inlet design pressure.

b. Two-Way Modulating: For inlet pressure of 15 psig or less, the pressure drop shall be 80 percent of inlet design pressure. For inlet pressure higher than 15 psig, the pressure drop shall be 42 percent of inlet design pressure.

2.28. ENERGY AND FLOW METERS

A. Refer to Section 239210 for energy and flow meter requirements.

2.29. CONTROL DAMPERS

A. Refer to Section 233300 for control damper requirements.

2.30. ELECTRICAL CONNECTIONS

A. Provide 24V transformers for all control equipment fed by low-voltage (100 to 600 V) power feeders. Coordinate the exact requirements with the Electrical Contractor.

B. Refer to Section 230511 and Division 26 for electrical requirements.

PART 3 - EXECUTION

3.1. GENERAL INSTALLATION

A. Exposed wire nuts, including in plenum, will not be acceptable. All connections will be made inside a rated enclosure.

B. Smoke detectors, high and low limit thermostats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset. Provide contacts that allow DDC software to monitor safety switch status.

C. Coordinate fire alarm relay connections to the fire alarm system with the fire alarm installer.

D. Verify that duct, pipe, and equipment-mounted devices are installed before proceeding with installation.

E. Install labels and nameplates to identify control components according to Section 230553.

F. Install hydronic instrument wells, valves, and other accessories according to Section 232116.

G. Install refrigerant instrument wells, valves, and other accessories according to Section 232300.

H. Install duct volume-control dampers according to Sections 233113.

I. Install energy and flow meters according to Section 239210.

3.2. SENSOR INSTALLATION

A. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices 48 inches above the floor per ADA requirements. The location(s) to be selected by the Engineer. No sensor shall be mounted until the Engineer gives specific location instructions. Do not install sensor(s) on the inside of exterior building walls (including column fur outs) unless explicitly approved by Engineer.

B. 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.

C. Install outdoor air temperature and humidity sensors on north wall at designated location with sun shield.

D. Install mixing plenum sensors in a serpentine manner horizontally (not vertically) across duct. Support each bend with a capillary clip.

E. Install temperature sensors minimum 5-feet downstream of air terminal units.

F. Install high accuracy, duct-mounted combination temperature and humidity sensor where a humidity sensor is specified to be used in humidifier control sequences.

G. Provide thermowells to Mechanical Contractor for installation. Mechanical Contractor to “stub-up” any thermowell which is too long to install directly into piping. Install heat-conducting fluid in thermowell prior to installing sensor.

H. Install heat-conducting fluid where strap-on temperature sensors contact piping. Clean piping prior to installation. Insulate around sensor.

I. Wall Modules:

1. Limit set point adjustment to plus or minus 3 deg F unless otherwise specified on the Drawings.

2. Wall module shall be programmed such that it can be used for TAB support.

J. Sensor Guards: Install aspirating guards on thermostats in the following locations:

1. Building entrances.

2. Public areas.

3. Where indicated.

3.3. PRESSURE SENSOR INSTALLATION

A. Supply (Positive) Duct Static Pressure: Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.

B. Return (Negative) Duct Static Pressure: Pipe low-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.

C. Room Pressure: Pipe appropriate pressure sensor port (positive space: high pressure, negative space: low pressure) to room. Pipe opposite pressure point to reference outside of room. Connect to stainless steel, metal mesh snubber mounted to white 2-inch by 4-inch plate at locations on drawings.

D. Building Static Pressure: Pipe pressure sensor's low-pressure port to the static pressure port located on the outside of the building through outside air reference kit. Mount kit per manufacturer’s instructions. Pipe high-pressure port to stainless steel, metal mesh snubber mounted to white 2-inch by 4-inch plate at locations on drawings.

E. Pressure transducers, except those controlling VAV boxes, shall be located in control panels, not on monitored equipment or on ducts. Mount transducers in a vibration-free location accessible for service without use of ladders or special equipment.

F. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before tee for water gauges.

G. Install differential pressure sensor valve manifolds and eye level, and pipe water from mains down to valve manifold.

3.4. AIR FLOW SWITCHES INSTALLATION

A. Install air flow switches with manufacturers recommended straight duct diameters in horizontal ducts with switch located on the top of the duct.

B. Adjust factory settings to actual field conditions.

C. Install on wet-well fans to indicate ventilation operation or failure.

3.5. CURRENT SWITCHES / TRANSDUCER INSTALLATION

A. Wire may be “wrapped” around CT to obtain better status indication.

B. CTs requiring commissioning/startup will be done per factory installation instructions.

3.6. INDOOR AIR QUALITY SENSOR INSTALLATION

A. Install carbon monoxide (CO) monitoring systems as indicated.

1. Provide CO monitoring systems for the enclosed levels of the parking garage. Provide complete coverage of the enclosed levels of the parking garage and provide systems for each level. A CO monitoring system shall not cover an area on more than one level and the failure of any component shall not affect more than one level.

2. Locate sensing points on walls and columns at 5 to 6 feet above floor level. Locate one sensing point per 7500 square-feet. Do not locate sensing points closer than 6ft to traffic lanes.

3.7. INDOOR AIR QUALITY SENSORS FOR HAZARDOUS CLASSIFIED AREAS INSTALLATION

A. Install oxygen deficiency monitoring, combustible gas detection (Methane and floating flammable liquids), and toxic gas (Hydrogen Sulfide) for wet-wells and other locations as indicated and required by NFPA 820.

B. Install sensors, accessories, tubing, alarm and notification devices in accordance with the manufacturer’s recommendations.

3.8. THERMOSTAT INSTALLATION

A. Install Low-Limit Duct Thermostat (Freezestat, LTD) in ducts and plenums in a serpentine manner horizontally (not vertically) across duct. Support each bend with a capillary clip. The element covers a maximum of 12 inches above and below sensing element. At the bottom of the duct or plenum, the row with the tail end of the sensing element shall be a maximum of 6 inches from the bottom.

3.9. RELAY INSTALLATION

A. Relays will be mounted at a location where pilot light is visible from floor.

3.10. ACTUATOR INSTALLATION

A. Wire parallel actuators according to manufacturer's recommendations.

B. Check operation of valve/damper-actuator combination to confirm that actuator modulates valve/damper smoothly throughout stroke to both open and closed positions. Check valve for proper close-off.

C. Damper Actuators:

1. Install automatic dampers according to Section 233300.

2. Mount actuators directly on damper shaft or jackshaft unless shown as a linkage installation.

3. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5 degrees in the open position, manually close the damper, and then tighten linkage.

4. Provide necessary mounting hardware and linkages for actuator installation.

5. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures. Provide access door per specifications for any actuator inside of ductwork.

D. Valve Actuators: Connect actuators to valves with adapters approved by actuator manufacturer.

3.11. VALVE INSTALLATION

A. Refer to the Control Valve Application Schedule at end of section.

B. Where not provided from the factory, install pressure/temperature test ports (Pete's Plugs) for testing of pressure differential across the PIC valve.

C. For pressure independent control valves with electronic flow metering, coordinate with mechanical contractor to ensure 5 pipe diameters of straight pipe entering valve.

D. Mount actuators for steam valves at an angle compared to vertical. Do not mount actuator directly above steam valve.

3.12. CONTROL VALVE APPLICATIONS

A. Provide control valve types listed in the Control Valve Application Schedule below, unless otherwise noted on plans, details, diagrams or equipment schedules.

CONTROL VALVE APPLICATION SCHEDULE					
	SERVICE	CONFIGURATION	PIPE SIZES	VALVE TYPE	
HYDRONIC SYSTEMS	HEATING COILS	2-WAY 2-POSITION	2-INCHES AND SMALLER	PD	BALL
			2 1/2-INCHES AND LARGER	PD	BUTTERFLY
		2-WAY MODULATING	2-INCHES AND SMALLER	PI	BALL
			2 1/2-INCHES AND LARGER	PI	BALL / GLOBE
		3-WAY MODULATING	2-INCHES AND SMALLER	PD	BALL
			2 1/2-INCHES AND LARGER	PD	BALL / GLOBE
	COOLING COILS	2-WAY 2-POSITION	2-INCHES AND SMALLER	PD	BALL
			2 1/2-INCHES AND LARGER	PD	BUTTERFLY
		2-WAY MODULATING	2-INCHES AND SMALLER	PI	BALL
			2 1/2-INCHES AND LARGER	PI	BALL / GLOBE
		3-WAY MODULATING	2-INCHES AND SMALLER	PD	BALL
			2 1/2-INCHES AND LARGER	PD	BALL / GLOBE
	CT CDW BYPASS	2-WAY MODULATING	ALL SIZES	PD	BUTTERFLY
		3-WAY MODULATING	ALL SIZES	PD	GLOBE
	EQUIPMENT BYPASS	2-WAY 2-POSITION	2-INCHES AND SMALLER	PD	BALL
			2 1/2-INCHES AND LARGER	PD	BUTTERFLY
		3-WAY 2-POSITION	2-INCHES AND SMALLER	PD	BALL
			2 1/2-INCHES AND LARGER	PD	BALL / GLOBE
		3-WAY MODULATING	2-INCHES AND SMALLER	PD	BALL
			2 1/2-INCHES AND LARGER	PD	BALL / GLOBE
	HEAT EXCHANGERS	2-WAY MODULATING	2-INCHES AND SMALLER	PI	BALL
			2 1/2-INCHES AND LARGER	PI	BALL / GLOBE
	ISOLATION VALVES	2-WAY 2-POSITION	2-INCHES AND SMALLER	PD	BALL
			2 1/2-INCHES AND LARGER	PD	BUTTERFLY
STEAM SYSTEMS	HEATING COILS	2-WAY MODULATING	2-INCHES AND SMALLER	PD	GLOBE
			2 1/2-INCHES AND LARGER	PD	GLOBE
	HUMIDIFIERS	2-WAY MODULATING	2-INCHES AND SMALLER	PD	GLOBE
			2 1/2-INCHES AND LARGER	PD	GLOBE
	POINT-OF-USE EQUIPMENT	2-WAY MODULATING	2-INCHES AND SMALLER	PD	GLOBE
			2 1/2-INCHES AND LARGER	PD	GLOBE
	HEAT EXCHANGERS	2-WAY MODULATING	2-INCHES AND SMALLER	PD	GLOBE
			2 1/2-INCHES AND LARGER	PD	GLOBE
	ISOLATION VALVES	2-WAY 2-POSITION	2-INCHES AND SMALLER	PD	GLOBE
			2 1/2-INCHES AND LARGER	PD	GLOBE

NOTES:

1. COIL AND EQUIPMENT WITH PRESSURE DEPENDENT CONTROL VALVES REQUIRE BALANCING VALVES. REFER TO 232119.
2. COIL AND EQUIPMENT WITH PRESSURE INDEPENDENT CONTROL VALVES DO NOT REQUIRE BALANCING VALVES.
3. 3-WAY VALVES SHALL BE CONFIGURED FOR MIXING OR DIVERTING BASED ON INDICATED ORIENTATION.

END OF SECTION

SECTION 23 90 20 – BAS FIELD CONTROLLERS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes BAS field controllers.

1.2. DESCRIPTION

A. Field Controllers are defined as any intelligent device, provided under any specification Division, by any contractor, which communicates with other Field Controllers or a Network Controller in an intelligent manner, beyond a simple contact closure or analog signal.

B. Clarifications:

C. Field Controllers shall communicate utilizing the following protocol:

1. BACnet, in accordance with the latest ASHRAE Standard 135.

D. Other protocol communication, such as Modbus, shall be acceptable when specifically requested for engineering approval.

E. Field Controllers shall fundamentally communicate via the protocol(s) listed. Field Controllers which communicate over a non-specified protocol and then convert to a specified protocol via a protocol converter, router or gateway are not acceptable.

1.3. SUBMITTALS

A. Comply with the requirements of Section 239000.

1.4. QUALITY ASSURANCE

A. Comply with BAS general requirements in Section 239000.

B. BACnet Controller Requirements: Certify that the controllers proposed to be provided meet each one of the following requirements:

1. Provide BACnet Controllers that BACnet Testing Laboratory listed (v12 or later) as specified herein:

    a. BACnet Building Controller (B-BC)

    b. BACnet Advanced Application Controller (B-AAC)

    c. BACnet Application Specific Controller (B-ASC)

2. All BACnet Controllers shall use the following communication specifications and achieve performance as specified herein:

    a. All controllers shall be able to communicate peer-to-peer without the need for a Network Control Unit (NCU). Any controller on the MS/TP Data Link/Physical layer shall be able to act as a Master to allow for the exchange and sharing of data variables and messages with any other controller connected on the same communication cabling. Sub-controllers (aka "slave" controllers) are not acceptable.

PART 2 - PRODUCTS

2.1. MANUFACTURERS

A. Comply with the requirements of Section 239000.

2.2. DDC CONTROLLERS

A. General Requirements

1. DDC Controllers shall be provided for AHUs, MAUs, Chillers, Boilers, Water Systems, Unit Ventilators, Fan Coils, Heat Pumps, Variable Air Volume (VAV) Terminals and other applications as needed.
2. The application control program for each controller shall be resident within the same enclosure as the input/output circuitry, which translates the sensor signals.
3. All control sequences programmed into the controller shall be stored in non-volatile memory, which is not dependent upon the presence of a battery, to be retained.
    a. Controller shall be able to return to full normal operation without user intervention after a power failure of unlimited duration.
4. Controller shall be 32 bit microprocessor-based. They shall also be multi-tasking, real-time digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules.
5. Controller size shall be sufficient to fully meet the requirements of this specification and the sequence of operations.
6. Each TCU shall have sufficient memory, to support its own operating system and databases, including: control processes, maintenance support applications, custom processes, and manual override monitoring.
7. Each controller shall support monitoring of the following types of inputs and outputs, without the addition of equipment outside the Controller enclosure:
    a. Digital inputs from dry contact closure, pulse accumulators, voltage sensing.
    b. Analog inputs of 4-20 mA, 0-10 Vdc, thermistor and RTD in the range 0 to 350,000 ohm.
    c. Digital outputs of 24 Vac/dc (contact closure).
    d. Analog outputs of 4-20 mA and 0-10 Vdc.
8. Controller analog or universal input shall use a 16 bit A/D converter. Controllers with less than 16 bit A/D converters must provide all analog input sensors with 4-20ma transmitters.

9. Controller analog or universal output shall use a 10 bit D/A converter.

10. Each controller shall have a minimum of 10% spare capacity for each point type for future point connection.

    a. Provide all processors, power supplies and communication controllers complete so that the implementation of a point only requires the addition of the appropriate point input/output termination module and wiring.

    b. As a minimum, provide one of each type of point available on the controller.

11. Controllers shall function normally under ambient conditions of 32 to 120 deg F and 5 to 90 percent RH (non-condensing).

12. Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly.

13. Each controller shall perform its primary control function independent of other NCU controller LAN communication, or if LAN communication is interrupted.

    a. Reversion to a fail-safe mode of operation during LAN interruption is not acceptable.

14. The controller shall receive its real-time data from the NCU controller time clock to ensure LAN continuity.

15. Each controller shall include algorithms incorporating proportional, integral, and derivative (PID) gains for all applications.

    a. All PID gains and biases shall be field-adjustable by the user via terminals as specified herein.

B. Local Control Units (LCU): For primary systems (including but not limited to AHU, MAU, chiller, boiler, and water systems.)

1. Controller shall be fully programmable, and the programming software shall have a library of pre-built, tested, and user re-definable control sequences for a wide range of typical HVAC applications.

2. Each LCU shall have sufficient memory to support any required energy management applications or alarm management applications.

3. Provide sufficient internal memory for the specified control sequences and have at least 25% of the memory available for future use.

4. LCU shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all panel components.

5. Should the LCU memory be lost for any reason, the user shall have the capability of reloading the controller software via the BAS LAN operator workstation or server.

6. Provide an onboard network communication jack for connection to the network (RJ-45 or equivalent quick connect)

C. Terminal Control Units (TCU): For secondary systems (including but not limited to VAV, fan-powered VAV, fan coil, radiation, and reheat coils.)

1. Where a TCU is deemed to have insufficient capability for the application, whether due to memory, power, I/O, etc., the Contractor will provide an appropriate LCU in lieu of a TCU.

2. TCU shall be powered from a 24 Vac source.

3. TCU shall be fully programmable, and the programming software shall have a library of pre-built, tested, and user re-definable control sequences for a wide range of typical HVAC applications.

   a. Operating programs shall be field selectable for specific applications.

   b. In addition, specific applications may be modified to meet the user's exact control strategy requirements, allowing for additional system flexibility.

   c. TCU that require factory changes of all applications are not acceptable.

4. TCU which is provided with on-board sensors or devices, such as pressure sensors or actuators, will meet the requirements as set forth in 239010. Where sensors or devices do not meet those requirements, a those sensors or devices will be provided separately.

D. Configurable Terminal Control Units (CTCU): For secondary systems (including but not limited to VAV, fan-powered VAV, fan coil, radiation, and reheat coils.)

1. CTCU will meet all the requirements set forth in the TCU section above, as well as the additional requirements below:

2. CTCU may be provided so long as they can be configured “out-of-the-box” to meet the sequences of operation on the drawings. Configurations which require special programming beyond the factory configuration options are not acceptable, and an LCU or TCU will be provided instead.

3. Provide documentation in submittals where CTCUs are proposed to show configuration details and how they will meet the sequence.

2.3. ANALOG CONTROLLERS

A. Step Controllers: 6 or 10-stage type, with heavy-duty switching rated to handle loads and operated by electric motor.

B. Electric, Outdoor-Reset Controllers: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range, adjustable set point, scale range minus 10 to plus 70 deg F, and single- or double-pole contacts.

C. Electronic Controllers: Wheatstone-bridge-amplifier type, in steel enclosure with provision for remote-resistance readjustment. Identify adjustments on controllers, including proportional band and authority.

D. Fan-Speed Controllers: Solid-state model providing field-adjustable proportional control of motor speed from maximum to minimum of 55 percent and on-off action below minimum fan speed. Controller shall briefly apply full voltage, when motor is started, to rapidly bring motor up to minimum speed. Equip with filtered circuit to eliminate radio interference.

E. Receiver Controllers: Single- or multiple-input models with control-point adjustment, direct or reverse acting with mechanical set-point adjustment with locking device, proportional band adjustment, authority adjustment, and proportional control mode.

1. Remote-control-point adjustment shall be plus or minus 20 percent of sensor span, input signal of 3 to 13 psig.
2. Proportional band shall extend from 2 to 20 percent for 5 psig.
3. Authority shall be 20 to 200 percent.
4. Air-supply pressure of 18 psig input signal of 3 to 15 psig, and output signal of zero to supply pressure.
5. Gages: 1 1/2-inch diameter, 2.5 percent wide-scale accuracy, and range to match transmitter input or output pressure.

PART 3 - EXECUTION

3.1. FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
2. Test and adjust controls and safeties.
3. Test calibration of electronic controllers by disconnecting input sensors and stimulating operation with compatible signal generator.
4. Test each point through its full operating range to verify that safety and operating control set points are as required.
5. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
6. Test each system for compliance with sequence of operation.
7. Test software and hardware interlocks.

B. BAS Verification:

1. Verify that instruments are installed before calibration, testing, and loop or leak checks.
2. Comply with verification requirements of Section 239000.

C. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

3.2. ADJUSTING

A. Comply with adjustment requirements of Section 239000.

B. Adjust initial temperature and humidity set points.

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

END OF SECTION

SECTION 23 90 30 – BAS NETWORK LEVEL CONTROLS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes BAS network level controls.

1.2. DESCRIPTION OF WORK

A. Network Level Controls are defined as any device which aggregates data, either via hardwired or wireless, from one or more Field Controllers. Most commonly they are at the building level, defined as a Network Control Unit (NCU) herein, and communicate with various piece of mechanical equipment. Network Level Controls might also aggregate data from lower-Network Level Controls to a higher-Network Level Controls, such as from a building level to a campus or enterprise level. Network Level Controls are typically where the operator interface resides. Network Level Controls could refer to an application-specific piece of hardware provide by the overall BAS System Manufacturer, or to software which resides on a Windows-based PC or server.

1.3. SUBMITTALS

A. Comply with the requirements of Section 239000.

1.4. QUALITY ASSURANCE

A. Comply with BAS general requirements in Section 239000.

B. In addition to the Quality Assurance requirements set forth in 239000 the following shall be required:

1. Installer Qualifications: Automatic control system manufacturer's authorized representative who is trained and approved for installation of system components required for this project.

2. Manufacturer Specific Training Certification (JCI or ALC): The system programmer(s) shall have successfully completed the appropriate certification training courses related to the applicable versions of the software installed.

PART 2 - PRODUCTS

2.1. GENERAL REQUIREMENTS

A. Description: The DDC system shall have all points exposed to network with the associated manufacture software framework. The control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, accessories and software connected to distributed controllers operating in multiuser, multitasking environment on token-passing network and programmed to control mechanical systems. An operator workstation permits interface with the network via dynamic color graphics with each mechanical system, building floor plan, and control device depicted by point-and-click graphics. The control system shall be complete and fully operable.

B. Network Control Unit Licenses: All NCUs shall have permanent licenses that remain with the owner. The system shall not prevent another vendor from accessing and modifying the software with the proper admin login. Proprietary software shall not be required for future vendors to integrate with this system. Provide all proprietary JAR (Java ARchive) files or other drivers used on the NCU hardware to the owner. If any hardware or software must be modified, repaired, or replaced in the future, any qualified vendor shall be able to do so without the support of this system's vendor.

C. Software and Equipment Licenses: All systems shall be "open". Issue a copy of all software and licensing information to the owner such that the Owner will own all licensing and project software. All configuration tools and programs necessary to configure the Owner's system, including the project specific data base, graphics and application programming code shall be provided to the Owner.

D. Coordinate with owner on specific version of Niagara to be installed.

2.2. OPEN ARCHITECTURE

A. DDC system shall provide an open, interoperable and integrated architecture with a peer-to-peer networked, stand-alone, distributed control system with the capability to integrate BACnet/IP, BACnet MS/TP, LonWorks, Modbus IP, Modbus RTU, Modbus TCP, and proprietary legacy communication protocols in a single interoperable system. The system shall be accessible by web browsers with secured access.

B. Control System Server: Structural Query Language (SQL) using Open Database Connectivity (ODBC) compliant server database stored on a server. Systems requiring a proprietary database and/or user interface programs are not acceptable.

2.3. NETWORKS

A. Virtual Local Area Network (VLAN): The minimum 100 Mbps Ethernet VLAN shall connect a local control system server, operator workstation and multiple Network Control Units (NCUs). The VLAN shall support XML internet protocol, Hypertext Transfer Protocol (HTTP), Simple Object Access Protocol (SOAP), Java, BACnet and LonWorks.

B. Local Area Network (LAN): The minimum 100 Mbps Ethernet LAN shall comply with IEEE Standard 802.3 and use 100 Base-TX, UTP-8 wire, Category 6 (Cat 6) cabling.

C. Remote Access: The VLAN shall be accessible without proprietary software by commonly available web browsers (i.e. Microsoft Internet Explorer, Google Chrome, Mozilla Firefox and Apple Safari) with tiered username and password security access.

1. Internet Access: The Owner shall provide high-speed internet connection for access to the VLAN. The Owner shall provide temporary secured access, for the duration of the project through the one-year walk-through, to the VLAN users.

2. Graphics: The web browser view of the graphics shall be the same as provided by the Operator Interface Graphic Software when accessed directly on the Owner's network. The web browser graphics shall support URL hypertext links for other locations on the internet and intranet.

2.4. NETWORK LEVEL CONTROLS HARDWARE

A. Microsoft Windows Based Hardware: Refer to Section 239040.

B. Network Control Unit (NCU):

1. Network Control Unit (NCU) will be provided by manufacturers listed in 239000.
2. Each NCU shall have sufficient memory, to support its own operating system and databases, including control processes, energy management applications, alarm management applications, historical/trend data for points specified.
3. The communication protocols utilized for peer-to-peer communications between NCUs and/or Supervisors will be BACnet/IP and lastly SNMP. Use of a proprietary communication protocol for peer-to-peer communications between NCUs and/or Supervisors is not allowed.

2.5. WEB SUPERVISOR

A. Where multiple NCUs are to be installed, a matching Supervisor will be installed to integrate the multiple NCUs and to provide a fully functional system.

2.6. [AUTOMATED LOGIC WEBCTRL BUILDING AUTOMATION SYSTEM]

A. Where multiple NCUs are to be installed, a WebCTRL building management system server will be installed to integrate the multiple NCUs.

2.7. [JOHNSON CONTROLS INC. (JCI) METASYS NETWORK AUTOMATION ENGINE (NAE) OR NETWORK CONTROL ENGINE (NCE)]

A. Where multiple NCUs are to be installed, a JCI Metasys building management system server will be installed to integrate the multiple NCUs.

PART 3 - EXECUTION

3.1. INSTALLATION

A. Install NCUs in a control panel at locations on the drawings. Coordinate data drops and control panel requirements as per 239000.

B. Install Supervisor software at location at the highest-Network Level Controls, unless otherwise specified.

C. Operator Interface will reside at the Supervisor location, unless otherwise specified.

END OF SECTION

SECTION 23 90 40 – BAS FRONT-END SOFTWARE AND HARDWARE

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes BAS control system front-end software and hardware.

1.2. SUBMITTALS

A. Comply with the requirements of Section 239000.

1.3. QUALITY ASSURANCE

A. Comply with BAS general requirements in Section 239000.

B. System Performance: The system shall comply with the following minimum performance requirements:

1. Graphic Display: Display graphic with minimum 20 dynamic points with current data within 10 seconds.
2. Graphic Refresh: Update graphic with minimum 20 dynamic points with current data within 8 seconds.
3. Object Command: Reaction time of less than 2 seconds between operator command of a binary object and device reaction.
4. Object Scan: Transmit change of state and change of analog values to control units or workstation within 6 seconds.
5. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.

PART 2 - PRODUCTS

2.1. DDC SOFTWARE

A. General Requirements:

1. Alarm processing, messages, and reactions.
2. Trend logs retrievable in spreadsheets and database programs.
3. Alarm and event processing.
4. Object and property status and control.
5. Automatic restart of field equipment on restoration of power.
6. Data collection, reports, and logs. Include standard reports for the following:

a. Current values of all objects.

b. Current alarm summary.

c. Disabled objects.

d. Alarm lockout objects.

e. Logs.

7. Custom report development.

8. Utility and weather reports.

9. Workstation application editors for controllers and schedules.

10. Maintenance management.

B. Custom Application Software:

1. English language oriented.

2. Full-screen character editor/programming environment.

3. Allow development of independently executing program modules with debugging/simulation capability.

4. Support conditional statements.

5. Support floating-point arithmetic with mathematic functions.

6. Contains predefined time variables.

C. Archiving: Automatically store data base back-up and trend data at one operator workstation and the server without operator action. Operator shall be able to manually download entire controller databases or parts thereof.

2.2. OPERATOR INTERFACE GRAPHIC SOFTWARE

A. General Requirements:

1. Graphic software shall provide user-friendly and intuitive operation of the systems with minimal training and experience at each level of interface, including operator workstations, diagnostic terminal units, and mobile applications. It shall allow multi-tasking for third-party software and alarm graphics to display when in other software windows.

2. Dynamic Data Displays: Automatically update point values at a minimum frequency of every 10 seconds or less. Data point displays shall be color-coded and indicate normal, abnormal, alarm, signal loss and override conditions.

3. Override Function: Graphic software shall allow an override for each digital data point value and for each change in analog status. The override value shall reside in the equipment controller not just at the OWS.

a. Password Protection: Provide password protection for each level of importance as determined with the Owner.

b. Override Tracking: Each override shall be tagged with the associated operator's identification number, name or initials.

2.3. MICROSOFT WINDOWS BASED HARDWARE

A. Operator Workstation (OWS): One (1) PC-based microcomputer(s) manufactured by Dell, Lenovo or Hewlett Packard.

1. Motherboard: With 4 integrated USB 3.0 ports, 4 integrated USB 2.0 ports, integrated Intel Pro 10/100/1000 Ethernet card, integrated audio, bios, and hardware monitoring.
2. Processor: Intel Core i7, Quad (4)-core, 3.40 GHz.
3. Random-Access Memory (RAM): 12 GB, DDR4 SDRAM
4. Graphics: Video adapter, minimum 1600 x 1200 pixels, 3 GB video memory.
5. Hard-Disk Drive: NVMe SSD.
6. CD-ROM Read/Write Drive: 48x24x48.
7. Monitor: 27-inch flat-panel LED color monitor with 1920x1080 resolution, 120 Hz refresh rate and HDMI, VGA and DVI-D inputs.
8. Keyboard: QWERTY, 105 keys in ergonomic shape, wireless
9. Mouse: Three button, optical, wireless
10. Uninterruptible Power Supply: 2 kVa.
11. Operating System: Microsoft Windows 10 64-bit with the most recent service packs and system updates.
12. ASHRAE 135 Compliance: Workstation shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
13. Antivirus Software: 3-year Symantec (or equal by Owner request) subscription service of antivirus software.
14. Location: **TBD**

B. Diagnostic Terminal Unit (DTU): One (1) portable notebook-style, PC-based microcomputer terminal manufactured by Dell, Lenovo or Hewlett Packard.

1. Motherboard: With 2 integrated USB 3.0 ports, 2 integrated USB 2.0 ports, integrated Intel Pro 10/100/1000 Ethernet card, integrated audio, bios, and hardware monitoring.
2. Processor: Intel Core i7, Quad (4)-core, 2.80 GHz.
3. Random-Access Memory (RAM): 8 GB, DDR3L SDRAM
4. Graphics: Video adapter, minimum 1600 x 1200 pixels, 2 GB video memory.
5. Monitor: 17-inch LED color.
6. Keyboard: QWERTY 105 keys.

7. Hard-Disk Drive: 1.0 TB SATA with 6 GB/s transfer rate.
8. CD-ROM Read/Write Drive: 48x24x48.
9. Pointing Device: Touch pad or other internal device.
10. Operating System: Microsoft Windows 10 64-bit with the most recent service packs and system updates.
11. Antivirus Software: 3-year Symantec (or equal by Owner request) subscription service of antivirus software.

C. Printers: Provide one (1) report and alarm printer connected for each Operator Workstation.

1. Printer: Printer(s) shall be a color inkjet printer, 1440 x1440 dpi photo quality color resolution, internal 1MB buffer memory, minimum 8 pages per minute in black and 4 pages per minute in color, 100 sheet 8.5-inch by 11-inch cassette feed, 100 sheet output cassette, with separate dedicated color and black and white cartridges. Supply one spare set of ink cartridges and 1000 sheets of paper.

PART 3 - EXECUTION

3.1. WORKSTATION INSTALLATION

A. Desktop Workstations Installation:

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

B. Portable Workstations Installation:

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

C. PRINTER INSTALLATION

1. Provide printer(s) at location(s) directed by Owner:
2. Install printer software on workstations and verify that software functions properly.

END OF SECTION

SECTION 23 92 10 – ENERGY AND FLOW METERS

PART 1 - GENERAL

1.1. SUMMARY

A. Section includes BAS energy and flow meters for piping and duct systems.

1.2. SUBMITTALS

A. Product Data: Provide data for product indicating compliance with the requirements of this project.

1. Wiring Diagrams: Power, signal and control wiring.

2. Seismic Qualification Certificates: Provide certification for the equipment and its components and accessories that they have been tested and meet the requirements for use in seismic applications in accordance with Virginia Construction Code.

B. Close-Out Submittals:

1. Operation and Maintenance Data: For energy and flow meters to include in operation and maintenance manuals.

1.3. QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70 by a qualified testing agency accepted by the Authority Having Jurisdiction and marked for intended location and application.

1. Listing agencies of electrical and mechanical equipment shall be accredited by the North Carolina Building Code Council (NCBCC).

1.4. WARRANTY

A. Warranty: Provide two-year manufacturer’s parts and labor warranty for each energy and flow meter.

PART 2 - PRODUCTS

2.1. AIR FLOW MEASURING STATIONS

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

1. Air Monitor Corporation

2. Ebtron

3. Paragon Controls

4. Tek-Air Systems

5. Kurz Instruments Inc.

B. Duct Air Flow Measuring Stations, Thermal Dispersion Type: Type 304 or 316 stainless steel sensing elements with multiple ports, 24Vac power and 4 to 20 mA signal. The sensing element shall be specifically designed to measure air flow in duct. Ebtron (Gold Series, Duct and Plenum) or equal.

1. Accuracy: Plus or minus 3 percent at 100 to 5,000 fpm.

2. Operating Conditions, Air Stream: Minus 20 to plus 140 deg F and 0 to 99 percent humidity, non-condensing.

3. Pressure Drop: 0.20-inches wg at 4,000 fpm maximum.

4. Noise Generation: NC-40 maximum, self-generated sound level.

C. Fan Inlet Air Flow Measuring Stations, Thermal Dispersion Type: Type 304 or 316 stainless steel sensing elements with multiple ports, 24Vac power and 4 to 20 mA signal. The sensing element shall be specifically designed to measure air flow of a centrifugal fan at the inlet cone. For double-inlet fans, provide one set of elements for each inlet. Ebtron (Gold Series, Fan Inlet) or equal.

1. Accuracy: Plus or minus 2 percent at 100 to 5,000 fpm.

2. Operating Conditions, Air Stream: 32 to 140 deg F and 0 to 99 percent humidity, non-condensing.

3. Pressure Drop: 0.20-inches wg at 4,000 fpm maximum.

4. Noise Generation: NC-40 maximum, self-generated sound level.

D. Transmitter: Heavy-duty construction with LED display with 4 to 20 mA air flow and temperature output signals and BACnet MS/TP RS-485 output for interface with the building automation system (BAS).

A. Insertion Flow Meter suitable for Class 1, Division 1 or Division 2 hazardous classified areas: Insertion type thermal mass flow meter for condensing gas flow measurements. C-276 alloy sensor, 316L stainless steel or C-276 alloy sensor support, 6”-60” probe length. Aluminum dual chamber polyester powder-coated type 4, IP66 enclosure, or stainless steel, or remote-only polycarbonate. Two 4 to 20 mA output, two relays, and one non-isolated 4 to 20 mA input signals. Up to five gas calibrations. USB or RS-485 Modbus output for interface with the building automation system (BAS). Provide intrinsic safety barriers, wiring, and seals.

1. Velocity Range:

   a. 0 to 4,000 SFPM Air

   b. 0 to 3,000 SFPM Biogas

   c. 0 to 2,000 SFPM CH_4.

2. Accuracy: Plus or minus 1 percent of reading at +20 SFPM

3. Repeatability: 0.25% reading.

4. Process pressure rating: Up to 150 PSIG

B. Process temperature rating: -40 to 257 deg F

2.2. FLOW AND THERMAL ENERGY METERS

A. Electromagnetic Hydronic Flow Meters, In-Line Type: Inline electromagnetic hydronic flow meter with cast-iron body, Class 150 flanges, epoxy coated steel flow tube, Type 316 stainless steel sensing electrodes and PTFE liner. Onicon F-3000 Series or equal.

1. Pressure Rating: 300 psig.
2. Medium Temperature Rating: 250 deg F.
3. Output Signals: 4-20 mA (flow rate) and pulse (totalization)
4. Accuracy: +/- 1.0 percent at 1 to 20 feet/second.
5. Control Interface: BACnet IP.
6. BTU Meter: Outputs include total energy (BTU), energy rate (BTU/hour), flow rate (gallons/minute) and supply and return temperatures (deg F).
7. Remote Display: Remote wall-mounted LCD display of total energy (BTU), energy rate (BTU/hour), flow rate (gallons/minute) and supply and return temperatures (deg F) with 120VAC/24VDC transformer.

B. Electromagnetic Hydronic Flow Meters, Insertion Type: Insertion electromagnetic hydronic flow meter with Type 316 stainless steel wetted metal components. Meter shall be able to be inserted and removed by hand without system shutdown. Onicon F-3500 Series or equal.

1. Pressure Rating: 400 psig.
2. Medium Temperature Rating: 250 deg F.
3. Output Signals: 4-20 mA (flow rate) and pulse (totalization).
4. Accuracy: +/- 1.0 percent at 2 to 20 feet/second.
5. Fluid Flow: Single direction.
6. Control Interface: BACnet IP
7. BTU Meter: Outputs include total energy (BTU), energy rate (BTU/hour), flow rate (gallons/minute) and supply and return temperatures (deg F).
8. Remote Display: Remote wall-mounted LCD display of total energy (BTU), energy rate (BTU/hour), flow rate (gallons/minute) and supply and return temperatures (deg F) with 120VAC/24VDC transformer.

C. Turbine Hydronic Flow Meters, Insertion Type: Insertion single turbine hydronic flow meter with Type 316 stainless steel wetted metal components. Meter shall be able to be inserted and removed by hand without system shutdown. Onicon F-1000 Series or equal.

1. Pressure Rating: 400 psig.
2. Medium Temperature Rating: 250 deg F.

3. Operating Range: 100:1.

4. Output Signals: 4-20 mA (flow rate).

5. Accuracy: +/- 2.0 percent at 1 to 20 feet/second.

6. Fluid Flow: Single direction.

7. Fluid Flow: Bidirectional.

8. Control Interface: BACnet IP.

9. BTU Meter: Outputs include total energy (BTU), energy rate (BTU/hour), flow rate (gallons/minute) and supply and return temperatures (deg F).

10. Remote Display: Remote wall-mounted LCD display of total energy (BTU), energy rate (BTU/hour), flow rate (gallons/minute) and supply and return temperatures (deg F) with 120VAC/24VDC transformer.

D. Thermal Mass Natural/Propane Gas Flow Meters, Insertion Type: Insertion thermal mass flow meter suitable for natural and propane gas with Type 316 stainless steel wetted metal components and flow conditioner. Meter shall be able to be inserted and removed by hand without system shutdown. Onicon F-5000 Series or equal.

1. Pressure Rating: 500 psig.

2. Medium Temperature Rating: 150 deg F.

3. Operating Range: 100:1

4. Output Signals: 4-20 mA (flow rate) and pulse (totalization).

5. Accuracy: +/- 1.0 percent of surface feet/minute with 500 to 7000 reading.

6. Control Interface: BACnet IP.

7. Remote Display: Remote wall-mounted LCD display of flow rate (cubic feet/hour) and total flow (cubic feet) with 120VAC/24VDC transformer.

E. Compound Hydronic Flow Meters, In-Line Type (NPS 2 to 6-inches): Inline compound-flow meter with turbine and low flow disc measuring elements designed for wide range of water flow measuring, lead-free copper alloy body, cast-iron flanges, two direct-reading magnetic-driven roll-sealed registers and complies with AWWA C702. Neptune TRU/FLO series or equal.

1. Pressure Rating: 150 psig.

2. Medium Temperature Rating: 80 deg F.

3. Operating Range: 1000:1

4. Output Signals: 4-20 mA (flow rate) and pulse (totalization).

5. Accuracy: +/- 1.5 percent of volume.

6. Control Interface: BACnet IP.

7. Remote Display: Remote wall-mounted LCD display of flow rate (gallons/minute) and total flow (gallons) with 120VAC/24VDC transformer.

F. Ultrasonic Hydronic Flow Meter, Clamp-On Type: Ultrasonic clamp-on hydronic flow meter utilizing differential transit time method in direct or reflect mode with non-wetted ultrasonic transducers. Onicon F-4000 Series or equal.

1. Medium Temperature Rating: 250 deg F.
2. Operating Range: 400:1
3. Output Signals: 4-20 mA (flow rate) and pulse (totalization).
4. Accuracy: +/- 1.0 percent at 1 to 40 feet/second.
5. Control Interface: BACnet IP.
6. BTU Meter: Outputs include total energy (BTU), energy rate (BTU/hour), flow rate (gallons/minute), total flow (gallons) and supply and return temperatures (deg F).
7. Remote Display: Remote wall-mounted LCD display of flow rate (gallons/minute) and total flow (gallons) with 120VAC/24VDC transformer.

2.3. ELECTRICAL CONNECTIONS

A. Provide 24V transformers for all control equipment fed by low-voltage (100 to 600 V) power feeders. Coordinate the exact requirements with the Electrical Contractor.

B. Comply with the requirements of Section 230511 and Division 26.

PART 3 - EXECUTION

3.1. INSTALLATION

A. Install labels and nameplates to identify control components according to Section 230553.

B. Install hydronic instrument wells, valves, and other accessories according to Section 232116.

3.2. AIR FLOW MEASURING STATION INSTALLATION

A. Install air flow measuring stations in locations indicated and required to perform the sequences of operation. Install stations in accordance to the manufacturer's recommendations.

1. Do not install air flow measuring station sensors and probes until all sanding and grinding activities are complete to protect them from accumulating dust and debris.
2. Coordinate with duct installer to provide minimum 12/12 duct access door where probe sensors are not easily accessible for maintenance to clean. Install multiple for ducts over 48" wide.

3.3. FLOW AND ENERGY METER APPLICATION

A. Flow Meters for Piping Systems:

1. Chilled Water: Electromagnetic, Insertion Type.
2. Heating Water: Electromagnetic, Insertion Type.
3. Natural Gas and Propane: Thermal Mass.
4. Domestic Water (2 to 6 inches NPS): Compound.
5. Domestic Water (1 1/2 inches NPS and smaller): Turbine, Insertion Type.

3.4. FLOW AND ENERGY METER INSTALLATION

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

B. Install flow meter elements in accessible positions in piping systems.

C. Install wafer-orifice flow meter elements between pipe flanges.

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

E. Mount thermal-energy meters on wall if accessible; if not, provide brackets to support meters.

F. Install grounding rings on the inlet and outlet side of each electromagnetic style meter when installed in non-metallic or lined piping. Grounding ring dimensions, spacing and wiring shall meet manufacturer’s recommendations.

G. Install flow and energy meters as recommended by the manufacturer and as follows, whichever is stricter:

1. Electromagnetic, In-line Type: Straight pipe length shall be minimum 3 times the pipe diameter on the inlet and 2 times on the outlet.
2. Electromagnetic, Insertion Type: Straight pipe length shall be minimum 10 times the pipe diameter on the inlet and 5 times on the outlet.
3. Turbine, Insertion Type: Straight pipe length shall be minimum 10 times the pipe diameter on the inlet and 5 times on the outlet.
4. Thermal Mass, Insertion Type: Straight pipe length shall be minimum 10 times the pipe diameter on the inlet and 5 times on the outlet.
5. Vortex, In-Line Type: Straight pipe length shall be minimum 10 times the pipe diameter on the inlet and 5 times on the outlet.
6. Vortex, Insertion Type: Straight pipe length shall be minimum 10 times the pipe diameter on the inlet and 5 times on the outlet.
7. Spring-Loaded Variable-Area, In-Line Type: Straight pipe length shall be minimum 6 times the pipe diameter on the inlet and 3 times on the outlet.
8. Compound, In-Line Type: Per manufacturer.

9. Ultrasonic, Clamp-On Type: Straight pipe length shall be minimum 10 times the pipe diameter on the inlet and 5 times on the outlet.

3.5. CONNECTIONS

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

1. Connect flow meter-system elements to meters.
2. Connect flow meter transmitters to meters.
3. Connect thermal-energy meter transmitters to meters.

3.6. ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. Extend 120V power circuits from points provided to control voltage transformers. Where dedicated junction boxes have been provided, coordinate the exact locations with the Electrical Contractor. Where they have not, coordinate the spare circuit breakers to be used with the Electrical Contractor or Owner.

B. Install raceways, boxes, and cabinets according to Section 230511 and Division 26.

C. Install building wire and cable according to Section 230511 and Division 26.

D. Install signal and communication cable according to Section 230511 and Division 26. Comply with manufacturer’s installation guidelines.

1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
2. Install exposed cable in raceway.
3. Install concealed cable in raceway.
4. Bundle and harness multi-conductor instrument cable in place of single cables where several cables follow a common path.
5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
6. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.
7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.

E. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.

F. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

3.7. ADJUSTING

A. Set differential pressure flow transmitters for 0 and 100 percent values with 3-point calibration accomplished at 50, 90 and 100 percent of span.

B. Manually operate flow switches to verify that they make or break contact.

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

D. Adjust faces of meters to proper angle for best visibility.

END OF SECTION