Delivering water and power™

Construction Specification Manual

Salt River Project

Technical Specification Index – November 2024

Division 23

Division	Title	Updated
DIVISION 23:	**HEATING, VENTILATING AND AIR CONDIITIONING (HVAC)**	
230513	Common Motor Requirement for HVAC Equipment	Revised 04/22
230515	Common Work Results for HVAC	Revised 02/24
230516	Adjustable Frequency Drives for Variable Torque Applications	New 04/22
230519	Meters and Gages for HVAC Piping	Revised 04/22
230523	General-Duty Valves for HVAC Piping	Revised 04/22
230529	Hangers and Supports for HVAC Piping and Equipment	Revised 04/22
230548	Vibration Controls for HVAC Piping and Equipment	Revised 04/22
230553	Identification for HVAC Piping and Equipment	Revised 04/22
230593	Testing, Adjusting, and Balancing	Revised 04/22
230713	Duct Insulation	Revised 11/24
230719	HVAC Piping Insulation	Revised 04/22
230800	Commissioning of HVAC	New 04/22
230923	Instrumentation and Controls for HVAC	Revised 02/24
231123	Facility Natural Gas Piping	Revised 04/22
232113	Hydronic Piping	Revised 04/22
232114	Pre-Insulated Piping	New 04/22
232123	Hydronic Pumps	Revised 04/22
232300	Refrigerant Piping	Revised 04/22
232500	HVAC Water Treatment	Revised 04/22
233113	Metal Ducts	Revised 11/24
233300	Duct Accessories	Revised 06/23
233423	HVAC Power Ventilators	Revised 04/22
233433	Air Curtains	Revised 04/22
233600	Air Terminal Units	Revised 04/22
233713	Diffusers, Registers, and Grilles	Revised 04/22
233723	HVAC Gravity Ventilators	Revised 04/22
235700	Hydronic Heat Exchangers for HVAC	Revised 04/22
236100	Evaporative Coolers	Revised 04/22
236416	Centrifugal Water Chillers	Revised 04/22
236500	Cooling Towers	Revised 04/22
237313	Indoor Semi-Custom Air-Handling Units	Revised 04/22
237343	Packaged, Outdoor, Rooftop Units	New 04/22

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Construction Specification Manual

Salt River Project

Division	Title	Updated
237433	Dedicated Outdoor Air Units	New 04/22
237443	Outdoor, Semi-Custom Air-Handling Units	New 04/22
238123	Computer Room Air-Conditioners	Revised 04/22
238126	Split System Air-Conditioners	Revised 04/22
238146	Water Source Unitary Heat Pumps	Revised 04/22
238219	Fan-Coil Units	Revised 04/22

SECTION 23 05 13

COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 REFERENCES

A. AFBMA 9 - Load Ratings and Fatigue Life for Ball Bearings.

B. AFBMA 11 - Load Ratings and Fatigue Life for Roller Bearings.

C. IEEE 112 - Test Procedure for Polyphase Induction Motors and Generators.

D. NEMA MG 1 - Motors and Generators.

E. NFPA 70 - National Electrical Code

1.2 COORDINATION

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

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

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

1.3 ACTION SUBMITTALS

A. Product Data: For each motor including but not limited to, horsepower rating, voltage rating, amperage rating, ambient temperature rating, phasing, operating frequency, service factor, insulation class, frame size, motor efficiency, bearing type, etc.

1.4 CLOSEOUT SUBMITTALS

A. Operation Data: Include instructions for safe operating procedures.

B. Maintenance Data: Documentation shall include manufacturers model number, manufacturer's installation instructions, assembly drawings, bearing data including replacement sizes, lubrication instructions, adjustment procedures, inspection period, recommended cleaning methods and materials, testing methods, shaft grounding brush replacement procedures and calibration tolerances.

C. Statement of Guarantee: Include date of termination.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

A. Comply with NEMA MG 1 unless otherwise indicated.

B. Motors larger than 5HP to be 277V or 480V, 3 Phase if available at site.

C. Comply with IEEE 841 for severe duty motors.

D. Provide TEFC motors with anti-friction grease lubricated ball bearings, with a bearing AFBMA B-10 life of 100,000 hours and sealed from the environment. Provide factory lubrication of motors prior to shipment. Provide grease-lubricated bearings with relief fittings.

E. Provide ODP motors with sealed anti-friction grease lubricated ball bearings, with a bearing AFBMA B-10 life of 100,000 hours. Provide factory lubrication of motors prior to shipment. Provide grease-lubricated bearings with relief fittings.

F. Provide nameplates of stainless steel or other approved corrosion resistant material to provide a permanent legible marking, containing NEMA data plus guaranteed minimum efficiency. Attach nameplates and connection plates to the motor frame by rivets or screws.

G. Provide motors with conduit boxes that are fully rotatable, diagonally split, including gasket between cover and box, and box and frame, with threaded hubs and a grounding lug located within the box for ground conductor connection.

2.2 MOTOR CHARACTERISTICS

A. Indoor Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 1500 feet above sea level.

B. Outdoor Duty: Continuous duty at ambient temperature of 50 deg C and at altitude of 1500 feet above sea level

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

2.3 POLYPHASE MOTORS

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

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

C. Service Factor: 1.15.

D. Rotor: Random-wound, squirrel cage.

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

F. Temperature Rise: Match insulation rating.

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. Energy- and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
   3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
   4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

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

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

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

2.6 DIRECT DRIVE ELECTRONICALLY COMMUTATED MOTORS

A. High performance direct drive, long-life, low-temperature brushless DC electronically commutated motor (EC-Motor) with external rotor and integrated maintenance-free electronic circuitry and electronics.

B. The motor shall be manufactured with maintenance-free, permanently lubricated ball bearings and shall be statically and dynamically balanced in accordance with ISO 1940 part 1.

C. The motor shall be closed, protection level IP 54, thermal class 155 with permissible operating temperature of -13°F to 140°F.

D. Motor efficiency class shall comply with IE4. Fan characteristic curves indicate measurements on a chamber test in accordance with ISO5801.

E. External rotor motors shall meet the requirements for circulating electric machines set forth in DIN EN 60 034-1 (VDE 0530 Part 1).

F. Motors shall be listed per UL 1995.

G. Provided motor controller configurable for motor speed control via BACnet interface (MSTP), Modbus, 0-10 VDC input or 4-20 mA input.

H. 65KAIC SCCR disconnect shall be provided.

2.7 MANUFACTURERS

A. Subject to compliance with the requirements included in this section, for motors not included as part of a listed assembly provide products by one of the following:
   1. General Electric
   2. Emerson
   3. A. O. Smith
   4. U. S. Motors
   5. WEG
   6. Baldor

PART 3 - EXECUTION

3.1 INSTALLATION

A. Termination – 5HP and above
   1. At motor terminal box, mechanically terminate motor leads and conductors with crimped or compression “eyes”. Bolt eyes together, with lock washer and nut.
   2. Tape: First layer of tape is varnished Cambrick tape, tape over the Cambrick with self-sealing rubber wrap splicing tape. Finish with a wrap of #33 Scotch electrical tape (or equivalent).
   3. Terminal blocks: Mechanical connection terminal blocks for size, listing, and rating of motor conductors. Ample space required for insulated bushings and tape in terminal box.

B. MANUFACTURERS
   1. Cooper Bussmann
   2. Burndy
   3. Polaris

C. Install in accordance with manufacturer's instructions.

D. Check line voltage and phase and ensure agreement with nameplate.

END OF SECTION

SECTION 23 05 15

COMMON WORK RESULTS FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
1. Piping materials and installation instructions common to most piping systems.
2. Dielectric fittings.
3. Mechanical sleeve seals.
4. Sleeves.
5. Escutcheons.
6. Grout.
7. HVAC demolition.
8. Equipment installation requirements common to equipment sections.
9. Concrete bases.
10. Supports and anchorages.
11. Refrigerant management records.

1.2 DEFINITONS

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

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

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

D. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in duct shafts.

E. 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.

1.3 QUALITY ASSURANCE, COORDINATION, AND SAFETY

A. Steel Support Welding: Qualify processes and operators according to AWS D1.1, "Structural Welding Code--Steel."

B. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."

1. Comply with provisions in ASME B31 Series, "Code for Pressure Piping."
2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

C. Mechanical equipment and installation shall conform to the applicable codes and standards referenced on the construction documents.

D. Electrical Characteristics for HVAC Equipment: Equipment of higher electrical characteristics may be furnished provided such proposed equipment is approved in writing and connecting electrical services, circuit breakers, and conduit sizes are appropriately modified. If minimum energy ratings or efficiencies are specified, equipment shall comply with requirements.

E. Hot Works Permits:

1. “Hot Work” must be preauthorized and signed by the Project Manager via a signed “Owner Hot Work Permit”.
2. Burn permits are good for one full working day when burn activity occurs at project specific locations.
3. If a temporary working area (fab area) is established and approved by owner Risk Management and Owner PM, an approved hot work permit is good for up to 60 days.
4. Owner Burn Permits require 1-hour fire watch after an open flame or welding operation or a work generating/creating sparks or hot waste.

F. Piping, duct, equipment, and associated accessories kept on-site should be stored off the ground on skids, ends should be capped or sealed, and these items should be covered with plastic to prevent fouling or contact with excessive moisture. Piping, duct, and equipment should be cleaned of debris inside and out before installation and should be kept clean and protected throughout construction.

G. Coordinate requirements for access panels and doors for HVAC items requiring access that are concealed behind finished surfaces. Access panels and doors are specified in Division 08 Section 08 31 13 "Access Doors and Frames."

H. Shutdowns are to be requested with the respective Project Manager. Shutdowns must have a shutdown request filled out for the applicable trade and submitted to the respective trade's shop calendar 120 hours in advance, they shall include Methods of Procedure. Emergency situations will be addresses and a case by case basis.

I. Technicians working on the refrigerant circuits of equipment and appliances are required to possess Section 608 Technician Certification for the work they will be performing and be a Journeyman or supervised onsite by a Journeyman.

1.4 ACTION SUBMITTALS

A. Product Data: Furnish in numeric and diagrammatic format referencing the specification paragraph, location, drawing note, as appropriate to indicate the intended application.

B. Refrigerant Management Records

1. If a technician performs any work on the refrigerant circuit of equipment or an appliance, the technician will complete and submit a **Refrigerant Service Input Form** to the SRP O&M Representative with 2 calendar days after completion of the work.
2. If a technician removes equipment or an appliance containing refrigerant and surrenders it to SRP, the technician will complete and submit a **FACILITIES SERVICES DISPOSAL SUBMISSION FORM** to the SRP O&M Representative within 2 calendar days after completion of the work.
3. If a technician installs new equipment or appliances containing refrigerant, the technician will attach a picture of the nameplate listing the refrigerant charge requirements to the submitted **Refrigerant Service Input Form**.
4. All systems charged in the field at a value different than stated on the equipment name plate must be documented on a Refrigerant Service Input form and on a new engraved label permanently attached to the equipment near the point of charging.

1.5 CLOSEOUT SUBMITTALS

A. Operation Data: Include instructions for safe operating procedures.

B. Maintenance Data: Documentation shall include manufacturers model number, manufacturer's installation instructions, assembly drawings, maintenance procedures, adjustment procedures, inspection period, recommended cleaning methods and materials.

C. Statement of Guarantee: Include date of termination.

PART 2 - PRODUCTS

2.1 PIPE, TUBE, AND FITTINGS

A. Refer to individual Division 23 piping Sections for special joining materials not listed below.

B. Pipe Threads: ASME B1.20.1 for factory-threaded pipe and pipe fittings.

2.2 JOINING MATERIALS

A. Refer to individual Division 23 piping Sections for special joining materials not listed below.

B. Pipe-Flange Gasket Materials: ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness unless thickness or specific material is indicated.

C. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.

D. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

E. Brazing Filler Metals: AWS A5.8, BCuP Series or BAg1, unless otherwise indicated.

F. Welding Filler Metals: Comply with AWS D10.12.

G. Solvent Cements for Joining Plastic Piping:
   1. CPVC Piping: ASTM F 493.
   2. PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.

2.3 DIELECTRIC FITTINGS

A. Description: Combination fitting of copper alloy and ferrous materials with threaded, solder- joint, plain, or weld-neck end connections that match piping system materials.

B. Insulating Material: Suitable for system fluid, pressure, and temperature.

C. Dielectric Unions: Factory-fabricated, union assembly, for 250-psig minimum working pressure at 180 degrees F.

D. Dielectric Flanges: Factory-fabricated, companion-flange assembly with dielectric bolt insulators or fully floating, powder-coated, plate-steel, companion flange with EPDM insulator to prevent contact with copper flange adapter, for 150- or 300-psig minimum working pressure as required to suit system pressures.

E. Dielectric Couplings: Galvanized-steel coupling with inert and noncorrosive, thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225ºF.

F. Dielectric Nipples: Electroplated steel nipple with inert and noncorrosive, thermoplastic lining; plain, threaded, or grooved ends; and 300-psig minimum working pressure at 225ºF.

2.4 MECHANICAL SLEEVE SEALS

A. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve. Thunderline Link Seal or approved equal.

B. Sealing Elements: EPDM interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.

C. Pressure Plates: Carbon steel above grade and stainless steel below grade. Include two for each sealing element.

D. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating above grade and stainless steel below grade of length required to secure pressure plates to sealing elements. Include one for each sealing element.

2.5 SLEEVES

A. Galvanized-Steel Sheet: 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint.

B. Steel Pipe: ASTM A 53, Type E, Grade B, Schedule 40, galvanized, plain ends.

C. Cast Iron: Cast or fabricated "wall pipe" equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.

D. Stack Sleeve Fittings: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring and bolts and nuts for membrane flashing.
   1. Underdeck Clamp: Clamping ring with set screws.

2.6 ESCUTCHEONS

A. Description: Manufactured wall and ceiling escutcheons and floor plates, with an ID to closely fit around pipe, tube, and insulation of insulated piping and an OD that completely covers opening.

B. One-Piece or Two-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with polished chrome-plated finish.

2.7 GROUT

A. Description: ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.
   1. Characteristics: Post-hardening, volume-adjusting, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
   2. Design Mix: 5000-psi, 28-day compressive strength.
   3. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 HVAC DEMOLITION

A. Refer to Division 02 for general selective demolition requirements and procedures.

B. Disconnect, demolish, and remove HVAC systems, equipment, and components indicated to be removed. Items can only be abandoned in place with written permission from Owner.
   1. Piping to Be Removed: Remove portion of piping indicated to be removed and cap or plug remaining piping with same or compatible piping material.
   2. Piping to Be Abandoned in Place: Drain piping and cap or plug piping with same or compatible piping material. Label “Abandoned in Place.”
   3. Ducts to Be Removed: Remove portion of ducts indicated to be removed and plug remaining ducts with same or compatible ductwork material.

4. Ducts to Be Abandoned in Place: Cap or plug ducts with same or compatible ductwork material. Label “Abandoned in Place.”
5. Equipment to Be Removed: Disconnect and cap services, remove and discard equipment.
6. Equipment to Be Removed and Reinstalled: Disconnect and cap services and remove, clean, and store equipment; when appropriate, reinstall, reconnect, and make equipment operational. Operational test to be witnessed by Owner.
7. Equipment to Be Removed and Salvaged: Disconnect and cap services and remove equipment and deliver to Owner.
8. Perform cutting, fitting, and patching of HVAC equipment and building materials required to install new equipment and building materials in existing structures.
9. Protect the structure, furnishings, finishes, and adjacent materials not indicated or scheduled to be removed.
10. Provide and maintain temporary partitions or dust barriers adequate to prevent the spread of dust and dirt to adjacent areas.

C. If pipe, insulation, or equipment to remain is damaged in appearance or is unserviceable, remove damaged or unserviceable portions and replace with new products of equal capacity and quality.

3.2 PIPING SYSTEMS – COMMON REQUIREMENTS

A. Install piping according to the following requirements and Division 23 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 by Engineer.

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

D. Install piping at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

E. Install piping to conserve building space and not interfere with use of space.

F. Group piping wherever practical at common elevations and locations.

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

H. Install piping to permit servicing of valves and specialties.

I. Install piping at indicated slopes.

J. Install piping free of sags and bends.

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

L. Install piping to allow for expansion and contraction without stressing pipe, joints, or connected equipment.

M. Install piping to allow application of insulation.

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

O. Install escutcheons for exposed penetrations of piping through walls, ceilings, and floors.

P. Install sleeves for pipes passing through concrete and masonry walls, gypsum-board partitions, and concrete floor and roof slabs. In sprinklered buildings, extend floor sleeves 2 inches above top of floor.

Q. Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.
   1. Install steel pipe for sleeves smaller than 6 inches in diameter.
   2. Install cast-iron "wall pipes" for sleeves 6 inches and larger in diameter.
   3. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

R. Underground, Exterior-Wall Pipe Penetrations: Install cast-iron "wall pipes" for sleeves. Seal pipe penetrations using mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.
   1. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

S. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials as indicated on Drawings, or as required by authorities having jurisdiction.

T. Verify final equipment locations for roughing-in.

U. Refer to equipment specifications in other Sections for roughing-in requirements.

V. Install piping with the least quantity of joints practical, unless necessary for expansion and contraction.

3.3 PIPING JOINT CONSTRUCTION

A. Join pipe and fittings according to the following requirements and Division 23 specifying piping systems.

B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

D. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead- free solder alloy complying with ASTM B 32.

E. 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.

F. 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.

G. Welded Joints: Construct joints according to AWS D10.12, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.

H. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

I. Plastic Piping Solvent-Cement Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:
   1. Comply with ASTM F 402, for safe-handling practice of cleaners, primers, and solvent cements.
   2. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
   3. PVC Pressure Piping: Join schedule number ASTM D 1785, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule-number PVC pipe and socket fittings according to ASTM D 2855.
   4. PVC Nonpressure Piping: Join according to ASTM D 2855.

J. Plastic Pressure Piping Gasketed Joints: Join according to ASTM D 3139.

K. Plastic Nonpressure Piping Gasketed Joints: Join according to ASTM D 3212.

L. Fiberglass Bonded Joints: Prepare pipe ends and fittings, apply adhesive, and join according to pipe manufacturer's written instructions.

3.4 PIPING CONNECTIONS

A. Make connections according to the following, unless otherwise indicated:
   1. Install unions, in piping NPS 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.

2. Install flanges, in piping NPS 2-1/2 and larger, adjacent to flanged valves and at final connection to each piece of equipment.
3. Dry Piping Systems: Install dielectric unions and flanges to connect piping materials of dissimilar metals.
4. Wet Pipe Systems:
    a. NPS 4 and smaller: Install dielectric coupling or nipple fitting to connect piping materials of dissimilar metals.
    b. MPS 2-1/2 and larger: Install dielectric flange to connect piping materials of dissimilar metals.

3.5 TESTING OF PIPING SYSTEMS

A. Preparing for Testing:
1. Leave joints including welds un-insulated and exposed for examination during the test.
2. Provide temporary restraints for expansion joints which cannot sustain the reaction due to test pressure. If temporary restraints are not practical, isolate expansion joints from testing.
3. Isolate equipment that is not to be subjected to the test pressure from the piping. If a valve is used to isolate the equipment, its closure shall be capable of sealing against the test pressure without damage to the valve. Flanged joints at which blinds are inserted to isolate equipment need not be tested.
4. Install relief valves set at a pressure no more than 1/3 higher than the test pressure, to protect against damage by expansion of liquid or other source of overpressure during test.

B. Testing: Test hydronic piping as follows:
1. Use vents installed at high points in the system to release trapped air while filling the system. Use drains installed at low points for complete removal of that liquid.
2. Examine system to see that equipment and parts that cannot withstand test pressures are properly isolated. Examine test equipment to ensure that it is tight and that low pressure filling lines are disconnected.
3. Subject piping system to a hydrostatic test pressure which at every point in the system is not less than 1.5 times the design pressure. The test pressure shall not exceed the maximum pressure for a vessel, pump, valve, or other component in the system under test. Make a check to verify that the stress due to pressure at the bottom of vertical runs does not exceed either 90% of specified minimum yield strength, or 1.7 times the “SE” value in “Appendix A of B31.9, Code for Pressure Piping, Building Services Piping”.

C. After the hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components as appropriate, and repeat hydrostatic test until there are no leaks.

3.6 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS

A. Install equipment to allow maximum possible headroom unless specific mounting heights are 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 mechanical equipment to facilitate service, maintenance, and repair or replacement of components in accordance with the manufacturer’s written instructions. 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.

E. Lubrication points shall be accessible. Where this is impossible, provision shall be made for lubrication at an accessible location.

1. Where oil is used, an oil level indicator and capped, vented filling connection shall be provided and firmly mounted in an accessible space and shall be connected to the bearing with pipe(s) as required.
2. Where grease is used for lubricant, the pipe shall have a suitable lubricating fitting installed at the accessible end. Equipment shall be thoroughly lubricated before operation and at time work is accepted.

3.7 CONCRETE BASES

A. Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer's written instructions and according to seismic codes at Project.

1. Construct concrete bases of dimensions indicated, but not less than 6 inches larger in both directions than supported unit.
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.
7. Use 3000-psi, 28-day compressive-strength concrete and reinforcement as specified in Section 03 30 53 “Miscellaneous Cast-in-Place Concrete.”

3.8 ERECTION OF METL SUPPORTS AND ANCHORAGES

A. Refer to Section 05 43 00 “Slotted Channel Framing” and Section 05 50 00 “Metal Fabrications.”

B. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor HVAC materials and equipment.

C. Field Welding: Comply with AWS D1.1.

3.9 ERECTION OF WOOD SUPPORTS AND ANCHORAGES

A. Cut, fit, and place wood grounds, nailers, blocking, and anchorages to support, and anchor HVAC materials and equipment.

B. Select fastener sizes that will not penetrate members if opposite side will be exposed to view or will receive finish materials. Tighten connections between members. Install fasteners without splitting wood members.

C. Attach to substrates as required to support applied loads.

3.10 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.

END OF SECTION

SECTION 23 05 16

ADJUSTABLE FREQUENCY DRIVES FOR VARIABLE TORQUE APPLICATIONS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Variable Frequency Drive (VFD) consisting of a pulse width modulated (PWM) inverter designed for use with both asynchronous and permanent magnet motor

B. This Section is intended to supplement a drive schedule. The drive schedule identifies the optimized BOM for the project and includes quantity, size, voltage, enclosure rating, options, and harmonic mitigation requirements of the drives. IEEE 519-2014 is an electrical system standard for harmonic mitigation and not intended to be applied to an individual piece of equipment. Drives are only one of many sources of harmonics, thus verification of system IEEE 519-2014 compliance is beyond the VFD manufacturer’s scope. The EOR (Engineer of Record) is responsible for conducting an electrical system study and verifying the drive schedule has specified proper harmonic mitigation for the drives.

1.2 REFERENCES

A. Institute of Electrical and Electronic Engineers (IEEE)
   1. IEEE 519-2014, IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

B. Underwriters Laboratories (as appropriate)
   1. UL 508, 508A, 508C
   2. UL 61800, 61800-5-1, 61800-5-2
   3. UL 1995

C. The Association of Electrical Equipment and Medical Imaging Manufacturers (NEMA)
   1. NEMA ICS 7-2014, Adjustable Speed Drives

D. International Electrotechnical Commission (IEC)
   1. EN/IEC 61800

E. National Electric Code (NEC)
   1. NEC 430.120, Adjustable-Speed Drive Systems

F. CSA Group
   1. CSA C22.2 No. 274

G. International Building Code (IBC)
   1. IBC 2018 Seismic – referencing ASCE 7-16 and ICC AC-156

1.3 ACTION SUBMITTALS

A. Product Data: Complete technical product description with complete list of options provided. Portions of this specification not met shall be clearly indicated or the supplier and Contractor shall be liable to provide additional components required to meet this specification. Include the following:
   1. Outline dimensions, conduit entry locations and weights.
   2. Customer connection and power wiring diagrams.
   3. Building Information Modeling (BIM) objects shall be available online.

1.4 INFORMATIONAL SUBMITTALS

A. OSHPD preapproval, seismic certification, and installation requirements where applicable.

1.5 QUALITY ASSURANCE

A. Manufacturer Qualifications: Drives installed on this Project shall be from the same manufacturer and have a common user interface (control panel).
   1. Manufacturer shall have been engaged in the production of drives for a minimum of 30 years, and active front end drives for a minimum of 20 years.
   2. Drives that are manufactured by a third party and “brand labeled” shall not be acceptable.
   3. Drive manufacturers who do not build their own power boards and assemblies, or do not have full control of the power board manufacturing and quality control, shall be considered as a “brand labeled” drive.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Drives shall be UL labeled as a complete assembly. The base VFD shall be UL listed for 100 kA SCCR when installed in accordance with the manufacturer’s guidelines.

B. CE Mark – The base drive shall conform to the European Union Electromagnetic Compatibility directive, a requirement for CE marking. The base drive shall meet product standard EN 61800-3 for the First Environment restricted distribution (Category C2).

C. The base drive shall be seismically certified and labeled as such in accordance with the 2018 International Building Code (IBC):
   1. Seismic importance factor of 1.5, and minimum 2.5 SDS rating is required.
   2. Ratings shall be based upon actual shake test data as defined by ICC AC-156, via three axis of motion.
   3. Seismic certification of equipment and components shall be provided by OSHPD preapproval.

D. The base drive shall be SEMI-F47 certified. The drive must tolerate voltage sags to 50% for up to 0.2 seconds, sags to 70% for up to 0.5 seconds, and sags to 80% for up to one second.

2.2 MANUFACTURERS

A. Acceptable Manufacturers:
   1. Asea Brown Boveri (ABB)
   2. Adjustable Frequency Drives shall be ABB
   3. AFD's provided as a factory installed integral component of equipment shall also be ABB. If the equipment manufacturer cannot comply with this requirement, the factory provided drive is to be treated as a separate submittal.

2.3 VARIABLE FREQUENCY DRIVES

A. The drive package as specified herein and defined on the drive schedule shall be enclosed in a UL Type enclosure (enclosures with only NEMA ratings are not acceptable), completely assembled and tested by the manufacturer to ISO9001 standards.

B. The drive shall provide full rated output from a line of +10% to -15% of nominal voltage. The drive shall continue to operate without faulting from a line of +25% to -35% of nominal voltage.
   1. Drives shall be capable of continuous full load operation under the following environmental operating conditions:
      a. Ambient temperature -15 to 40° C (5 to 104° F).
      b. Altitude 0 to 1000 m (0 to 3,300 ft) above sea level.
      c. Humidity 5 to 95%, non-condensing.

C. Drives shall utilize the same Advanced Control Panel (keypad) user interface.
   1. Plain English text
      a. The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable).
      b. Safety interlock and run permissive status shall be displayed using predetermined application specific nomenclature, such as: Damper end switch, smoke alarm, vibration trip, and overpressure.
      c. Safety interlock, run permissive, and external fault status shall have the option of additional customized project specific terms, such as: AHU-1 End Switch, Office Smoke Alarm, CT-2 Vibration.
   2. The control panel shall include at minimum the followings controls:
      a. Four navigation keys (Up, Down, Left, Right) and two soft keys to simplify operation and programming.
      b. Hand-Off-Auto selections and manual speed control without having to navigate to a parameter.
      c. Fault Reset and Help keys. The Help key shall include assistance for programming and troubleshooting.

3. Multiple Home View screens shall be capable of displaying up to 21 points of information. Customizable modules shall include bar charts, graphs, meters, and data lists. Displays shall provide real time graphical trending of output power, frequency, and current within selectable intervals of 15/30/60 minutes and 24 hours.
4. The control panel shall display the following items on a single screen; output frequency, output current, reference signal, drive name, time, and operating mode (Hand vs Auto, Run vs Stop). Bi-color (red/green) status LED shall be included. Drive (equipment) name shall be customizable.
5. There shall be a built-in time clock in the control panel. The clock shall have a battery backup with 10 years minimum life span. Daylight savings time shall be selectable.
6. I/O Summary display with a single screen shall indicate and provide:
   a. The status/values of analog inputs, analog outputs, digital inputs, and relay outputs. Drives that require access to internal or live components to measure these values, are not acceptable.
   b. The programmed function of analog inputs, analog outputs, digital inputs, and relay outputs.
   c. The ability to force individual digital I/O high or low and individual analog I/O to desired value, for increased personal protection during drive commissioning and troubleshooting. Drives that require access to internal or live components to perform these functions, are not acceptable.
7. The drive shall automatically backup parameters to the control panel. In addition to the automatic backup, the drive shall allow two additional unique backup parameter sets to be stored. Backup files shall include a time and date stamp. In the event of a drive failure, the control panel of the original drive can be installed on the replacement drive, and parameters from that control panel can be downloaded into the replacement drive.
8. The control panel shall display local technical support contact information as part of drive fault status.
9. The control panel shall be removable, capable of remote mounting.
10. The control panel shall have the ability to store screen shots that are downloadable via USB.
11. The control panel shall have the ability to display a QR code for quick access to drive information.
12. The LCD screen shall be backlit with the ability to adjust the screen brightness and contrast, with inverted contrast mode. A user-selectable timer shall dim the display and save power when not in use.
13. The control panel shall include assistants specifically designed to facilitate start-up. Assistants shall include: First Start Assistant, Basic Operation, Basic Control, and PID Assistant.
14. Primary settings for HVAC shall provide quick set-up of parameters and customer interfaces to reduce programming time.
15. The drive shall be able to operate with the control panel removed.
16. The drive shall be able to support a Bluetooth Advanced Control Panel. The Bluetooth control panel shall be FCC and QDL (Qualified Design Listing) certified.

a. A free app (iOS and Android) shall replicate the control panel on a mobile device or tablet. The control panel's programming and control functionality shall function on the device. Customizing text, such as AHU-1 End Switch, shall be supported by the device's keyboard.

b. Bluetooth connectivity shall allow uploading, downloading, and emailing of parameter sets.

c. Bluetooth connectivity shall include two pairing modes: Always discoverable with a fixed passcode, and manual discovery with a unique generated passcode every pairing.

d. The Bluetooth antenna shall be in the control panel. Antennas that are integrated in the drive's control board, must include an external antenna, on drives mounted inside cabinets.

e. Bluetooth connectivity shall be capable of being switched off.

D. Drives shall have the following hardware features/characteristics as standard:

1. Two (2) programmable analog inputs shall accept current or voltage signals. Current or Voltage selection configured via control panel. Drives that require access to internal components to perform these functions, are not acceptable.

2. Two (2) programmable analog outputs. At least one of the analog outputs shall be adjustable for current or voltage signal, configured via control panel. Drives that require access to internal components to perform these functions, are not acceptable.

3. Six (6) programmable digital inputs. Digital inputs shall be programmable to support both active high and active low logic, and shall include adjustable on/off time delays. The digital input shall be capable of accepting both 24 VDC and 24 VAC.

4. Three (3) programmable Form-C relay outputs. The relay outputs shall include programmable on/off time delays. The relays shall be rated for a continuous current rating of 2 Amps. Maximum switching voltage of 250 VAC / 30 VDC. Open collector and Form-A relays are not acceptable. Drives that have less than (3) Form-C relay outputs shall provide an option card to provide additional relay outputs.

5. Drive terminal blocks shall be color coded for easy identification of function.

6. The drive shall include an isolated USB port for interface between the drive and a laptop. A non-isolated USB port is not acceptable.

7. An auxiliary power supply rated at 24 VDC, 250 mA shall be included.

8. At a minimum, the drives shall have internal impedance equivalent to 5% to reduce the harmonics to the power line. 5% impedance may be from dual (positive and negative DC link) chokes, or AC line reactor. Drives with only one DC link choke shall add an AC line reactor integral to the drive enclosure. Reference the drive schedule to determine if additional harmonic mitigation is required for the system to comply with IEEE 519-2014. If Active Front End (Ultra Low Harmonic) drives are specified on the schedule, they must meet the following characteristics (typically 20 Hp and larger):

a. An IGBT based active front end shall be used for mitigation of low frequency harmonics. A LCL filter shall be installed in front of the IGBTs to remove high frequency harmonics.

b. Limit the current distortion to 3% total harmonic current distortion, when measured at the lugs of the drive.
c. The drive shall provide full motor nameplate voltage while operating the motor at nameplate RPM. The output IGBTs must be modulating and in control of the motor during this 100% speed/load operating condition. The specified 3% current distortion and 1.0 displacement power factor shall be achievable during this operating condition.
d. The hardware structure of the front end shall boost the DC bus voltage by 10% during low line conditions.
e. Displacement power factor shall be 1.0 throughout the speed range.

9. The drive shall have cooling fans that are designed for field replacement. The primary cooling fan shall operate only when required and be variable speed for increased longevity and lower noise levels. Drives whose primary cooling fans are not variable speed, shall include a spare cooling fan.
10. The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute every 10 minutes, 130% overload for 2 seconds every minute. The minimum current rating shall meet or exceed the values in the NEC/UL table 430.250 for 4-pole motors.
11. The input current rating of the drive shall not be greater than the output current rating. Per NFPA 70 430.122, drives with higher input current ratings may require the upstream wiring, protection devices, and source transformers to be upsized.
12. Circuit boards shall be coated per IEC 60721-3-3; Chemical gasses Class 3C2 and Solid particles Class 3S2.
13. Earth (ground) fault detection shall function in both modulating (running) and non-modulating modes.
14. Coordinated AC transient surge protection system consisting of 4 MOVs (phase-to-phase and phase-to-ground), a capacitor clamp, and internal chokes. The MOVs shall comply with UL 1449 4th Edition. Drives that do not include coordinated AC transient surge protection shall include an external TVSS/SPD (Transient Voltage Surge Suppressor/Surge Protection Device).
15. The drive shall include a robust DC bus to provide short term power-loss ride through. The DC bus Joule to drive kVA ratio shall be 4.5 J/kVA or higher. An inertia-based ride through function should help maintain the DC bus voltage during power loss events. Drives with control power ride through only, are not acceptable.

E. Drives shall have the following software features as standard:

1. A Fault Logger that stores the last 16 faults in non-volatile memory.
   a. The most recent 5 faults save at least 9 data points, including but not limited to: Time/date, frequency, DC bus voltage, motor current, DI status, temperature, and status words.
   b. The date and time of each fault and fault reset attempt shall be stored in the Fault Logger.
2. An Event Logger that stores the last 16 warnings or events that occurred, in non-volatile memory.
   a. Events shall include, but not limited to: Warning messages, checksum mismatch, run permissive open, start interlock open, and automatic reset of a fault.
   b. The date and time of each event's start and completion points shall be stored in the Event Logger.

3. Programmable start method. Start method shall be selectable based on the application: Flying-start, Normal-start, and Brake-on-start.
4. Programmable loss-of-load (broken belt / coupling) indication. Indication shall be selectable as a control panel warning, relay output, or over network communications. This function to include a programmable time delay to eliminate false loss-of-load indications.
5. Motor heating function to prevent condensation build up in the motor. Motor heating adjustment, via parameter, shall be in “Watts.” Heating functions based only on “percent current” are not acceptable.
6. Advanced power metering abilities shall be included in the drive. Drives without these data points, must include a separate power meter with each drive.
   a. Instantaneous output power (kW)
   b. Total power broken down by kWh, MWh, and GWh units of measurement. Power meters that only display kWh and roll over or “max out” once the maximum kWh value is reached, are not acceptable. There shall be resettable and non-resettable total power meters within the drive.
   c. Time based kWh metering for: current hour, previous hour, current day, and previous day.
   d. Energy saving calculation shall be included that shows the energy and dollars saved by the drive.
7. The drive shall include a motor flux optimization circuit that will automatically reduce applied motor voltage to the motor to optimize energy consumption and reduce audible motor noise.
8. Run permissive circuit - There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command, the Drives shall provide a dry contact closure that will signal the damper to open. When the damper is fully open, an end-switch shall close, allowing the drive to run the motor.
   a. The drive shall also include a programmable start delay, for when an end-switch is not provided.
9. Start interlock circuit - Four separate start interlock (safety) inputs shall be provided. When safety is opened, the motor shall be commanded to stop. The control panel will display the specific safety(s) that are open. The status of each safety shall be transmitted over the network communications. Wiring multiple safeties in series is not acceptable.
10. External fault circuit – Three separate external fault inputs shall be provided. This circuit shall have the same features and functionality as the start interlock circuit, except it shall require a manual reset before the drive is allowed to operate the motor.
11. The drive shall include a switching frequency control circuit that reduces the switching frequency based on actual drive temperature and allows higher switching frequency settings without derating the drive. It shall be possible to set a minimum and a target switching frequency.
12. Visual function block adaptive programming allowing custom control schemes, minimizing the need for external controllers. I.e. cooling tower staging logic. A free software tool shall be used to configure adaptive programming.
13. The ability to automatically restart after an over-current, over-voltage, under-voltage, external fault, or loss of input signal protective trip. The number of restart attempts, trial time, and time between attempts shall be programmable. Each of

these faults may have automatic restart individually disabled via a parameter selection.

14. Three (3) programmable critical frequency lockout ranges to prevent the drive from operating the load continuously at an unstable speed/load.
15. Seven (7) programmable preset frequencies/speeds.
16. Two independently adjustable accel and decel ramps with 1 – 1800 seconds adjustable time ramps.
17. PID functionality shall be included in the drive.
    a. Programmable “Sleep” and “Wake up” functions to allow the drive to be started and stopped based on the level of a process feedback signal.
    b. The drive shall include an independent PID loop for customer use, assigned to an analog output. This PID loop may be used for cooling tower bypass valve control, chilled water valve, etc.
18. At least 4 parameter user sets that can be saved to the permanent memory and recalled using a digital input, timed function, or supervision function.
19. Drive shall be compatible with an accessory that allows the control board to be powered from an external 24 VDC/VAC source, allowing the drive control to remain powered by a UPS during an extended power outage.
20. A computer-based software tool shall be available to allow a laptop to program the drive. The drive shall be able to support programming without the need for line voltage. Necessary power shall be sourced via the laptop USB port.
21. The drive shall include a fireman’s override mode. Upon receipt of a contact closure from the Fire Alarm Life Safety system, the drive shall operate in a dedicated Override mode distinct and separate from the drive’s Normal operation mode. The following features will be available in the drive override function:
    a. The Override mode shall be secured by password to prevent changes once programmed.
    b. The drive shall ignore external inputs and commands not defined as part of the override function.
    c. Override operation mode shall be selectable between: single frequency, multiple fixed frequencies, follow an analog input signal, PID control, or come to a forced stop.
    d. High priority safeties shall stop the drive and lower priority safeties shall be ignored in Override mode.
    e. Drive faults shall be defined in Critical and Low priority groups. Critical faults shall stop the drive. Low priority faults shall be reset. Reset trials and timing shall be programmable.
    f. The drive shall be configurable to receive from 1 to 3 discrete digital input signals and operate at up to three discrete speeds.
22. The drive shall have multi-pump functionality and an intelligent master/follower configuration for controlling up to 8 parallel pumps equipped with drives. The drive shall have a parameter synchronization feature to program the PID, multi-pump, and AI parameters in parallel drives. The functionality to start and stop the pumps based on capacity, operating time, or efficiency of the pump to ensure each pump is operated regularly.
    a. The multi-pump functionality shall control:
        1) Flow Control
        2) Pressure Control
        3) Pump Alternation

F. Security Features:
1. The drive manufacture shall clearly define cybersecurity capabilities for their products.
2. The drive shall include password protection against parameter changes.
   a. There shall be multiple levels of password protection including: End User, Service, Advanced, and Override.
   b. The drive shall support a customer generated unique password between 0 and 99,999,999.
   c. The drive shall log an event whenever the drive password has been entered.
   d. The drive shall provide a security selection that prevents “back door” entry. This selection even prevents the drive manufacturer from being able to bypass the security of that drive.
   e. A security level shall be available that prevents the drive from being flashed with new firmware.
3. A checksum feature shall be used to notify the owner of unauthorized parameter changes made to the drive. The checksum feature includes two unique values assigned to a specific programming configuration.
   a. One checksum value shall represent user editable parameters in the drive except communication setup parameters. A second checksum value shall represent user editable parameters except communication setup, energy, and motor data parameters.
   b. Once the drive has been commissioned the two values can be independently saved in the drive.
   c. The drive shall be configurable to either: Log an Event, provide a Warning, or Fault upon a parameter change when the current checksum value does not equal the saved checksum value.
4. The “Hand” and “Off” control panel buttons shall have the option to be individually disabled (via parameter) for drives mounted in public areas.
5. The capability to disable Bluetooth on control panels that include Bluetooth functionality shall be provided.

G. Network Communications:
1. The drive shall have an EIA-485 port with removable terminal blocks. The onboard protocols shall be BACnet MS/TP, Modbus, and Johnson Controls N2. Optional communication cards for BACnet/IP, LonWorks, Profibus, Profinet, EtherNet/IP, Modbus TCP, and DeviceNet shall be available. The use of third-party gateways are not acceptable.
2. The drive shall have the ability to communicate via two protocols at the same time, one onboard protocol and one option card based protocol. Once installed, the drive shall automatically recognize optional communication cards without the need for additional programming.
3. The drive shall not require a power cycle after communication parameters have been updated.
4. The embedded BACnet connection shall be a MS/TP interface. The drive shall be BTL Listed to Revision 14 or later. Use of non-BTL Listed drives are not acceptable.

5. The drive shall be classified as an Applications Specific Controller (B-ASC). The interface shall support BIBBs defined by the BACnet standard profile for a B-ASC including, but not limited to:
    a. Data Sharing: Read Property Multiple-B, Write Property Multiple-B, COV-B
    b. Device Management: Time Synchronization-B
    c. Object Type Support: MSV, Loop
6. The drive's relay output status, digital input status, analog input/output values, Hand-Auto status, warning, and fault information shall be capable of being monitored over the network. The drive's start/stop command, speed reference command, relay outputs and analog outputs shall be capable of being controlled over the network. Remote drive fault reset shall be possible.

H. Disconnect – A circuit breaker or disconnect switch shall be provided when indicated on the drive schedule. The disconnect shall be door interlocked and padlockable. Drive input fusing shall be included on packaged units that include a disconnecting means. Disconnect configurations shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label. Disconnect packages manufactured by anyone other than the drive manufacturer, are not acceptable.

I. Bypass – Bypass drive packages shall be provided when indicated on the schedules on the Drawings or in the sequence of operations. Drive/bypass configurations shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label. Bypasses manufactured by anyone other than the drive manufacturer, are not acceptable.
1. The drive and bypass package shall be a complete factory wired and tested bypass system consisting of a padlockable disconnect device, drive output contactor, bypass contactor, and drive input fuses.
2. The drive and bypass package shall have a UL listed short circuit current rating of 100 kA, for 240 VAC and 480 VAC systems, and this rating shall be indicated on the rating label.
3. The bypass control shall be powered by a three-phase switch mode power supply with a voltage tolerance of +30%, -35%. Single-phase power supplies and control power transformers (CPT) are not acceptable.
4. The drive and bypass package shall be seismic certified and labeled to the IBC. Seismic importance factor of 1.5 rating is required and shall be based upon actual shake table test data as defined by ICC AC-156. Seismic certification of equipment and components shall be provided by OSHPD preapproval.
5. Bypass packages shall utilize a dedicated LCD bypass control panel (keypad) user interface. The bypass control panel must be a separate display from the drive control panel. Bypass packages that use a single shared drive/bypass control panel are not acceptable, due to that control panel acting as a single point of failure.
    a. The bypass shall include a two-line, 20-character LCD display. The display shall allow the user to access parameters and view:
        1) Bypass input voltage, current (Amps) and power (kW)
        2) Bypass faults, warnings, and fault logs
        3) Bypass operating time and energy consumption (resettable)
    b. The bypass control panel shall include the following controls:
        1) Four navigation keys (Up, Down, Enter, Escape)

   2) Bypass Hand-Off-Auto, Drive mode / Bypass mode selectors, Bypass fault reset
  c. The following indicating lights (LED PTT type) or control panel display indications shall be provided.
   1) Drive mode selected, Bypass mode selected
   2) Drive running, Bypass running
   3) Drive fault, Bypass fault
  d. Safety interlock and run permissive status shall be displayed using predetermined application specific nomenclature, such as: Damper end switch, smoke alarm, vibration trip, and overpressure.

6. Bypasses shall have the following hardware features/characteristics as standard:
  a. Six (6) digital inputs and five (5) Form-C relay outputs. The digital inputs shall be capable of accepting both 24 VDC and 24 VAC. The bypass control board shall include an auxiliary power supply rated 24 VDC, 250 mA.
  b. Drive isolation fuses shall be provided. Bypass designs which have no such fuses, or that only incorporate fuses common to both the drive and the bypass are not acceptable. Third contactor "isolation contactors" and service switches are not an acceptable alternative to drive isolation fuses.
  c. The bypass shall be able to detect a single-phase input power condition while running in bypass, disengage the motor, and provide a single-phase input power indication.
  d. The bypass shall be designed for stand-alone operation and be completely functional in both Hand and Automatic modes, even if the drive and/or drive's control board has failed. Network communications shall remain functional. Bypass systems that do not maintain full functionality in the event of a drive failure, are not acceptable.

7. Bypasses shall have the following software features as standard:
  a. Programmable loss-of-load (broken belt / coupling) indication shall be functional in drive and bypass mode.
  b. The bypass shall also support run permissive and start interlock control functionality, including start delay, as previously specified in the drive section.
  c. The bypass control shall monitor the status of the drive and bypass contactors and indicate when there is a welded contactor contact or open contactor coil.
  d. The bypass shall include a selection for either manual or automatic transfer to bypass. The automatic transfer mode shall allow the user to select the specific drive fault types that result in an automatic transfer to bypass. The automatic transfer mode shall not allow a transfer to bypass on motor related faults. Automatic transfer schemes that do not differentiate between fault types, are not acceptable.
  e. The bypass shall include the ability to select the operating mode of the system (Drive/Bypass) from either the bypass control panel or digital input.
  f. The bypass shall include a supervisory control mode that monitors the value of the drive's analog input (feedback). This feedback value is used to control the bypass contactor on/off state. The supervisory mode shall allow the user to maintain hysteresis control over applications such as cooling towers and booster pumps.
  g. Selectable Class 10, 20, or 30 electronic motor overload protection shall be included in both drive and bypass mode.

h. The drive and bypass shall be designed to operate as an integrated system when in Override mode. Whether operating in drive or bypass mode, the low priority safeties will be ignored, and high priority safeties will be followed. External start/stop commands will be ignored. There shall be four selectable Override modes:
   a) Bypass only, with two smoke control modes:
   b) Fixed pre-configuration of digital inputs
   c) Configurable high/low priority safeties and faults, to allow configuration to meet needs of local Authority Having Jurisdiction.
   2) Drive only
   3) Drive then transfer to bypass, in the event of a drive fault
   4) Force to Stop

8. Network communications – the bypass shall include BACnet MS/TP, Modbus, and Johnson Controls N2 as standard. The bypass BACnet implementation shall be BTL Listed to Revision 14 or later. Optional communication cards for BACnet/IP, LonWorks, Profibus, Profinet, Ethernet/IP, Modbus TCP, and DeviceNet shall be available.
   a. The bypass relay output status, digital input status, warning and fault information can be monitored over the network. Status information shall be monitored, including operating mode (drive vs bypass), current drawn in bypass mode, broken belt, and phase-to-phase voltage. The bypass start/stop command, force to bypass command, and relay outputs shall be capable of being controlled over the network.

PART 3 - EXECUTION

3.1 INSTALLATION

A. The responsible party shall install the drive in accordance with the recommendations of the drive manufacturer as outlined in the drive installation manual, as well as Owner Standard Specifications.

B. Power wiring shall be completed by the responsible party. Wiring shall be installed in accordance with the recommendations of the drive manufacturer as outlined in the installation manual.

C. Installation shall be in accordance with national, state, and local building and electrical codes as may be in force in the installation area.

3.2 START-UP

A. Start-up shall be provided for each drive by the ABB Certified Agent in the Territory.

3.3 PRODUCT SUPPORT

A. Factory trained application engineering and service personnel that are thoroughly familiar with the drive products offered shall be locally available at both the specifying and installation locations. A toll free 24/365 technical support line connected to factory support personnel located in the US and Canada shall be available.

B. Training shall include installation, programming and operation of the drive, bypass, and network communications. Owner training shall be provided locally upon request.

3.4 WARRANTY

A. The drive Product Warranty shall be 24 months from the date of certified start-up and acceptance for use by owner. The warranty shall include parts, on-site labor, and travel time and travel costs, or replacement of the complete drive as determined by the drive manufacturer’s technical support.

END OF SECTION

SECTION 23 05 19

METERS AND GAGES FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Thermometers.
   2. Gages.
   3. Test plugs.
   4. Water meters.
   5. Flowmeters.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product indicated, include materials and finishes, dimensions, and accuracies.
   1. For pressure gages, submit pressure range for each application.
   2. For thermometers, submit temperature range and scale divisions for each application.
   3. For water and flow meters, submit performance curves.

1.3 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: To include in O&M Manuals.

PART 2 - PRODUCTS

2.1 METAL-CASE, LIQUID-IN-GLASS THERMOMETERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Palmer - Wahl Instruments Inc.
   2. Trerice, H. O. Co.
   3. Weiss Instruments, Inc.
   4. Weksler Instruments Operating Unit; Dresser Industries; Instrument Div.

B. Case: Die-cast aluminum or brass, 9 inches long in mechanical rooms, 7 inches long elsewhere.

C. Tube: Red or blue reading, organic-liquid filled, with magnifying lens.

D. Tube Background: Satin-faced, nonreflective aluminum with permanently etched scale markings.

E. Window: Glass.

F. Connector: Adjustable type, 180 degrees in vertical plane, 360 degrees in horizontal plane, with locking device.

G. Stem: Copper-plated steel, aluminum, or brass for thermowell installation and of length to suit installation.

H. Accuracy: Plus or minus 1 percent of range or plus or minus 1 scale division to maximum of 1.5 percent of range.

I. Range: The maximum operating temperature should not exceed 75% of the full-scale range. The normal operating range should be in the middle half of the range (between 25% and 75% of the full-scale range); whenever possible.

2.2 THERMOWELLS

A. Manufacturers: Same as manufacturer of thermometer being used.

B. Description: Pressure-tight, threaded, socket-type metal fitting made for insertion into piping and of type, diameter, and length required to hold thermometer.

C. Materials: Brass in copper piping systems, Type 316 stainless steel in other piping systems.

D. Lagging Extensions: Provide in insulated piping systems, length suitable for insulation thickness.

2.3 PRESSURE GAGES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    1. AMETEK, Inc.; U.S. Gauge Div.
    2. Ashcroft Commercial Instrument Operations; Dresser Industries; Instrument Div.
    3. Ernst Gage Co.
    4. Eugene Ernst Products Co.
    5. Palmer - Wahl Instruments Inc.
    6. Trerice, H. O. Co.
    7. Weiss Instruments, Inc.
    8. Weksler Instruments Operating Unit; Dresser Industries; Instrument Div.

B. Direct-Mounting, Dial-Type Pressure Gages: Indicating-dial type complying with ASME B40.100.
    1. Case: Dry type, drawn steel, stainless steel, or cast aluminum, 4-1/2-inch diameter.

2. Pressure-Element Assembly: Bourdon tube, unless otherwise indicated.
3. Pressure Connection: Brass, NPS 1/4, bottom-outlet type unless back-outlet type is indicated.
4. Movement: Mechanical, with link to pressure element and connection to pointer.
5. Dial: Satin-faced, nonreflective aluminum with permanently etched scale markings.
6. Pointer: Red or other dark-color metal.
7. Window: Glass.
8. Ring: Metal.
9. Accuracy: Grade A, plus or minus 1 percent of middle half scale.

C. Range: The maximum operating pressure should not exceed 75% of the full-scale range. The normal operating range should be in the middle half of the range (between 25% and 75% of the full-scale range); whenever possible.

D. Pressure-Gage Fittings
1. Valves: NPS 1/4 brass gage cock with lever handles, or ¼” ball valve (see General Duty Valve specification).
2. Syphons: NPS 1/4 coil of brass tubing with threaded ends.
3. Snubbers: ASME B40.5, NPS 1/4 brass bushing with corrosion-resistant, porous-metal disc of material suitable for system fluid and working pressure.

2.4 MAGNEHELIC DIFFERENTIAL PRESSURE GAGES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Dwyer Series 2000

B. Indicating-dial type, low differential pressure gage.
1. 1. Die cast aluminum case and bezel, with acrylic cover, Exterior finish is coated gray to withstand 168-hour salt spray corrosion test.
2. Accuracy: ± 2 percent throughout range
3. Temperature Limits:20 to 140°F
4. Size:4" (101.6 mm) diameter dial face.
5. Process Connections:1/8" female NPT duplicate high and low pressure taps.

2.5 TEST PLUGS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Peterson Equipment Co., Inc.
2. Sisco Manufacturing Co.
3. Watts Industries, Inc.; Water Products Div.

B. Description: Corrosion-resistant brass or stainless-steel body with core inserts and gasketed and threaded cap, with extended stem for units to be installed in insulated piping.

C. Minimum Pressure and Temperature Rating: 500 psig at 200 degrees F.

D. Core Inserts: One or two self-sealing rubber valves.
   1. Insert material for air, water, oil, or gas service at 20 to 200 degrees F shall be CR.
   2. Insert material for air or water service at minus 30 to plus 275 degrees F shall be EPDM.

E. Test Kit: Furnish one test kit containing one pressure gage and adaptor, [one] [two] thermometer(s) and carrying case. Pressure gage, adapter probes, and thermometer sensing elements shall be of diameter to fit test plugs and of length to project into piping.

2.6 WATER METERS

A. Positive Displacement Water Meters:
   1. Manufacturers: Subject to compliance with requirements, provide a Badger Recordall Disc Series Meter with an HR-LCD 4-20 Scaled/Unscaled Register or comparable product by one of the following:
      a. ABB Water Meters, Inc.
      b. Grinnell Corporation; Mueller Co.; Hersey Meters.
      c. Water Specialties Corp.

2.7 VENTURI FLOWMETERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Armstrong Pumps, Inc.
   2. Gerand Engineering Co.
   3. Preso Meters Corporation.

B. Description: Differential-pressure design for installation in piping; with calibrated flow-measuring element, separate flowmeter, hoses or tubing, valves, fittings, and conversion chart compatible with flow-measuring element, flowmeter, and system fluid.

C. Construction: Bronze, brass, or factory-primed steel; with brass fittings and attached tag with flow conversion data.

D. Pressure Rating: 250 psig.

E. Temperature Rating: 250 deg F.

F. End Connections for NPS 2 and Smaller: Threaded.

G. End Connections for NPS 2-1/2 and Larger: Flanged or welded.

H. Range: Flow range of flow-measuring element and flowmeter shall cover operating range of equipment or system served.

I. Permanent Indicators: Suitable for wall or bracket mounting, calibrated for connected flowmeter element, and having 6-inch- diameter, or equivalent, dial with fittings and copper tubing for connecting to flowmeter element.
   1. Scale: Gallons per minute.
   2. Accuracy: Plus or minus 1 percent between 20 and 80 percent of range.

J. Portable Indicators: Differential-pressure type calibrated for connected flowmeter element and having two 12-foot hoses in carrying case.
   1. Scale: Gallons per minute.
   2. Accuracy: Plus or minus 2 percent between 20 and 80 percent of range.

K. Operating Instructions: Include complete instructions with each flowmeter.

2.8 PITOT-TUBE FLOWMETERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Dieterich Standard Inc.
   2. Preso Meters Corporation.
   3. Taco, Inc.

B. Description: Insertion-type, differential-pressure design for inserting probe into piping and measuring flow directly in gallons per minute.

C. Construction: Stainless-steel probe of length to span inside of pipe; with integral transmitter and direct-reading scale.

D. Pressure Rating: 150 psig minimum.

E. Temperature Rating: 250 degrees F minimum.

F. Display: Visual instantaneous rate of flow.

G. Integral Transformer: For low-voltage power connection.

H. Accuracy: Plus or minus 1 percent for liquids and gases.

2.9 FLOW INDICATORS

A. Provide a new ultrasonic strap on flow meter on piping where indicated.

B. Ultrasonic flow meter shall be General Electric DigitalFlow DF868 parametrics liquid ultrasonic flowmeter. Provide loop powered 3-wire platinum wetted RTD’s.
   1. Mount flow meter using bolted on or welded steel yoke.

2. Provide 4-20 mA analog instantaneous output and totalized output for Facilities Management System interface.
3. Install with minimum 10 pipe diameters straight pipe upstream and minimum 5 pipe diameters straight pipe downstream.
4. Provide with calibration kit.

PART 3 - EXECUTION

3.1 THERMOMETER APPLICATIONS

A. Install liquid-in-glass digital thermometers in the following locations:
1. Inlet and outlet of each hydronic zone.
2. Inlet and outlet of each hydronic coil in air-handling units and built-up central systems.
3. Inlet and outlet of each hydronic boiler and chiller.
4. Inlet and outlet of each hydronic heat exchanger.
5. Inlet and outlet of each hydronic heat-recovery unit.
6. Inlet and outlet of each thermal storage tank.
7. Outside-air, return-air, and mixed-air ducts.

B. Provide the following temperature ranges for thermometers:
1. Chilled Water (Indoors): 0 to 100 deg F, with 2-degree scale divisions.
2. Condenser Water or Chilled Water (outdoors): 0 to 160 deg F, with 2-degree scale divisions.

C. Air Ducts: Minus 40 to plus 110 deg F, with 2-degree scale divisions.

3.2 GAGE APPLICATIONS

A. Install pressure gages for discharge of each pressure-reducing valve.

B. Install pressure gages at chilled- and condenser-water inlets and outlets of chillers. Provide one gage across each tube bundle with gage cocks to permit independent measurement of inlet and outlet pressures.

C. Install pressure gages at heating-water inlets and outlets of boilers. Provide one gage across boiler with gage cocks to permit independent measurement of inlet and outlet pressures.

D. Install pressure gages at water inlets and outlets of heat exchangers. Provide one gage across each side of heat exchanger with gage cocks to permit independent measurement of inlet and outlet pressures.

E. Provide one gage with connection tubing and gage cocks for each pump to permit independent measurement of suction, discharge, and strainer inlet pressures.

F. Provide differential magnehelic gages across the air handling unit air filters. Monitor each section separately and monitoring and gauges shall have separate tubing.

G. Provide the following pressure ranges for pressure gage:
  1. Vacuum-Pressure Range: 30-in. Hg of vacuum to 15 psig of pressure.
  2. Range: The maximum operating pressure should not exceed 75% of the full-scale range. The normal operating range should be in the middle half of the range (between 25% and 75% of the full-scale range); whenever possible.

3.3 INSTALLATIONS

A. Install direct-mounting thermometers and adjust vertical and tilted positions. Ensure clearance is provided from piping and insulation to allow unobstructed viewing of thermometer.

B. Install thermowells with socket extending a minimum of 2 inches into fluid, but not less than one-third of diameter of pipe and in vertical position in piping tees where thermometers are indicated.

C. Prime thermowells with an approved heat transfer medium such as graphite or heat transfer paste to provide optimal accuracy and response time.

D. Duct Thermometer Support Flanges: Install in wall of duct where duct thermometers are indicated. Attach to duct with screws.

E. Install direct-mounting pressure gages in piping tees with pressure gage located on pipe at most readable position.

F. Install gage cock and snubber fitting in piping for each pressure gage for fluids (except steam).

G. Install test plugs in tees or Thread-o-lets in piping.

H. Assemble and install connections, tubing, and accessories between flow-measuring elements and flowmeters as prescribed by manufacturer's written instructions.

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

J. Install differential-pressure-gage flowmeter elements with at least minimum straight lengths of pipe upstream and downstream from element as prescribed by manufacturer's written instructions.

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

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

M. Install flowmeters where indicated on Drawings.

3.4 CONNECTIONS

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

B. Connect flowmeter system elements to meters.

3.5 ADJUSTING

A. Calibrate meters according to manufacturer's written instructions, after installation.

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

END OF SECTION

SECTION 23 05 23

GENERAL-DUTY VALVES FOR HVAC PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following general-duty valves:
   1. Copper-alloy ball valves.
   2. Ferrous-alloy butterfly valves.
   3. Spring-loaded, lift-disc check valves.
   4. Bronze gate valves.
   5. Cast-iron gate valves.

B. Related Requirements:
   1. Division 21 fire-suppression piping and fire pump Sections for fire-protection valves.
   2. Section 23 09 23 "Instrumentation and Controls for HVAC" for control valves and actuators.
   3. Section 23 05 53 "Identification for HVAC Piping and Equipment" for valve tags and schedules.

1.2 DEFINITIONS

A. CWP: Cold working pressure.

B. EPDM: Ethylene propylene copolymer rubber.

C. NBR: Acrylonitrile-butadiene, Buna-N, or nitrile rubber.

D. SWP: Steam working pressure

1.3 ACTION SUBMITTALS

A. Product Data: For each type of valve indicated.
   1. Include body, seating, and trim materials; valve design; pressure and temperature classifications; end connections; arrangement; dimensions; and required clearances.
   2. Include list indicating valve and its application.
   3. Include rated capacities; furnished specialties; and accessories.

1.4 QUALITY ASSURANCE

A. ASME Compliance: ASME B31.9 for building services piping valves.

B. ASME Compliance for Ferrous Valves: ASME B16.10 and ASME B16.34 for dimension and design criteria.

C. NSF Compliance: NSF 61 for valve materials for potable-water service.

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

1.5 DELIVERY, STORAGE, AND HANDLING

A. Prepare valves for shipping as follows:

1. Protect internal parts against rust and corrosion.
2. Protect threads, flange faces, grooves, and weld ends.
3. Set valves closed or slightly open.

B. Use the following precautions during storage:

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

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

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

2.2 VALVES, GENERAL

A. Refer to Part 3 "Valve Applications" for applications of valves.

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

C. Check Valves shall be spring loaded. Swing check valves are not acceptable.

D. Valve Sizes: Same as upstream pipe, unless otherwise indicated.

E. Valve Actuators:
1. Handwheel: Non-heating style of cast, malleable iron or aluminum for gear-operated, quarter-turn valves and valves other than quarter-tum types, located not more than 8 feet above walkways.
2. Chainwheel Actuators: For gear-operated, quarter-turn valves and valves other than quarter-turn types, located more than 8 feet above walkways. Adjust chain length to maintain 4 feet clearance above walkway floor. Provide chain bag at 6' clearance. Valve shall be installed so valve position indicator is visible from chain operator. If not, provide mirror or other viewing means.
3. Lever Handle: For quarter-turn valves NPS 6 and smaller, except plug valves. Provide infinite-position handle with open-position memory stop in balancing applications, and where indicated on Drawings.
4. Gear Operators: For quarter-turn valves larger than NPS 6, except plug valves.

F. Valves in Insulated Piping: With 2-inch stem extensions and the following features:
1. Gate Valves: With rising stem.
2. 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.
3. Butterfly Valves: With extended neck.

G. Valve Flanges: ASME B16.1 for cast-iron valves, ASME B16.5 for steel valves, and ASME B16.24 for bronze valves.

H. Solder Joint: With sockets according to ASME B16.18.
1. Caution: Use solder with melting point below 840 deg F for angle, check and gate valves; below 421 deg F for ball valves.

I. Threaded: With threads according to ASME B1.20.1.

2.3 COPPER-ALLOY BALL VALVES

A. Manufacturers
1. Two-Piece, full port Copper-Alloy Ball Valves:
   a. Honeywell Braukmann.
   b. Milwaukee Valve Company.
   c. Watts Industries, Inc.; Water Products Division
   d. Nibco Industries
   e. Conbraco Industries, Inc. Apollo Division

B. Copper-Alloy Ball Valves, General: MSS SP-110.

C. Description:
1. SWP Rating: 150 psig.
2. WOG Rating: 600 psig.
3. Body Design: Two piece with threaded body packing nut design (no threaded stem designs allowed) with adjustable stem packing.

4. Body Material: Bronze ASTM B 584 Alloy C844.
5. Ends: Threaded or Solder.
6. Seats: RPTFE or TFE(15% glass filled).
7. Stem: 316 Stainless steel blowout proof.
8. Ball: 316 Stainless steel, vented or bronze
9. Port: Full.

2.4 FERROUS-ALLOY BUTTERFLY VALVES

A. Manufacturers
1. Single-Flange, Ferrous-Alloy Butterfly Valves:
    a. Bray Controls; a division of Bray International
    b. Milwaukee Valve Company.
    c. Mueller Steam Specialty.
    d. Watts Industries, Inc.; Water Products Div.
2. Description:
    a. Standard: MSS SP-67, Type I.
    b. SWP Rating: NPS 12 and smaller minimum of 200 psig non-shock WOG.
    c. SWP Rating: NPS 14 and larger minimum of 150 psig non-shock WOG.
    d. Body Design: Full lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
    e. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
    f. Seat: EPDM.
    g. Stem: One- or two-piece stainless steel.
    h. Disc: Aluminum-bronze or type 316 stainless steel.
    i. Shaft: one or two pieces with type 316 or 416 stainless steel
    j. Operator: gear with memory stop

2.5 BRONZE SPRING-LOADED, LIFT-DISC CHECK VALVES

A. MANUFACTURERS:
1. Lift-Disc Check Valves:
    a. Milwaukee Valve Company.
    b. Mueller Steam Specialty.
    c. Watts Industries, Inc.; Water Products Div.
2. Description:
    a. Standard: FCI 74-1.
    b. SWP Rating: 125 psig.
    c. Body Material: Bronze.
    d. Ends: Threaded or solder joint.
    e. Disc Holder: Bronze.
    f. Disc ring: PTFE or TFE.
    g. Spring: Bronze

2.6 IRON CENTER GUIDED CHECK VALVES

A. Manufacturers:
  1. Iron center guided check valves
  2. Milwaukee Valve Company.
  3. Mueller Steam Specialty.
  4. Watts Industries, Inc.; Water Products Div.

B. Description:
  1. Standard: MSS SP-125.
  2. NPS 2-1/2 to NPS 12, CWP Rating: 200 psig
  3. NPS 14 to NPS 24, CWP Rating: 150 psig.
  4. Body Material: ASTM A 126, gray iron.
  5. Style: Compact wafer.
  6. Ends: Flanged.
  7. Seat: Bronze.

2.7 BRONZE GATE VALVES

A. Manufacturers:
  1. Bronze, Rising-Stem, Solid-Wedge Gate Valves:
    a. Grinnell Corporation.
    b. Milwaukee Valve Company.
    c. Watts Industries, Inc.; Water Products Div.
    d. Nibco Industries
  2. Description:
    a. Standard: MSS SP-80, Type 1.
    b. SWP Rating: 150 psig.
    c. Body Material: ASTM B 62, bronze with integral seat and screw-in bonnet.
    d. Ends: Threaded or solder joint.
    e. Stem: Copper-silicon Bronze.
    f. Disc: Solid wedge; bronze.
    g. Packing: Asbestos free.
    h. Handwheel: Malleable iron or bronze.

2.8 CAST IRON GATE VALVES

A. Manufacturers:
  1. Type I, Cast-Iron, Nonrising-Stem or Rising-Stem Gate Valves:
    a. Grinnell Corporation.
    b. Milwaukee Valve Company.
    c. Watts Industries, Inc.; Water Products Div.
    d. Nibco Industries
  2. Description:
    a. Standard: MSS SP-70, Type I.
    b. SWP Rating: 150 psig.

c. Body Material: ASTM A 126, gray iron with bolted bonnet.
d. Ends: Flanged.
e. Trim: Bronze.
f. Disc: Solid wedge.
g. Packing and Gasket: Asbestos free.

2.9 BRONZE GLOBE VALVES

A. Bronze Globe Valves with Nonmetallic Disc:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
a. Grinnell Corporation.
b. Milwaukee Valve Company.
c. Watts Industries, Inc.; Water Products Div.
d. Nibco Industries
2. Description:
a. Standard: MSS SP-80, Type 2.
b. SWP Rating: 150 psig.
c. Body Material: ASTM B 62, bronze with integral seat and screw-in bonnet.
d. Ends: Threaded or solder joint.
e. Stem: Copper-Silicone Bronze.
f. Disc: PTFE or TFE.
g. Packing: Asbestos free.
h. Handwheel: Malleable iron or bronze.

2.10 RESILIENT WEDGE UNDERGROUND GATE VALVES

A. Manufacturers:
1. Resilient Wedge Underground Gate Valves
a. Kennedy Valve Co.

B. Valves shall conform to the latest revision of AWWA Standard C509 covering resilient seated gate valves for water supply service.
1. The valves shall have an iron body, bonnet, and O-ring plate. The wedge shall be totally encapsulated with rubber.
2. The sealing rubber shall be permanently bonded to the wedge per ASTM D429.
3. Valves shall be supplied with O-ring seals at pressure retaining joints. No flat gaskets shall be allowed.
4. The valves shall be provided with 2” square operating nut.
5. Stems shall be cast copper alloy with integral collars in full compliance with AWWA. Stems shall operate with copper alloy stem nuts independent of wedge and of stem.
6. Stems shall have two O-rings located above thrust collar and one O-ring below. Stem O-rings shall be replaceable with valve fully opened and subjected to full pressure. The stems on 2” – 12” shall also have a low torque thrust bearing located above and below the stem collar to reduce friction during operation.

7. Waterway shall be smooth, unobstructed and free of pockets, cavities and depressions in the seat area. Valves 2” and larger shall accept a full size tapping cutter.
8. The body, bonnet and O-ring plate shall be fusion-bonded epoxy coated, both interior and exterior on body and bonnet. Epoxy shall be applied in accordance with AWWA C550 and be NSF 61 Certified.

2.11 IRON GLOBE VALVES

A. Iron Globe Valves:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    a. Grinnell Corporation.
    b. Milwaukee Valve Company.
    c. Watts Industries, Inc.; Water Products Div.
2. Description:
    a. Standard: MSS SP-85, Type I.
    b. SWP Rating: 200 psig.
    c. Body Material: ASTM A 126, gray iron with bolted bonnet.
    d. Ends: Flanged.
    e. Trim: Bronze.
    f. Packing and Gasket: Asbestos free.

2.12 CHAINWHEELS

A. Chainwheels
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    a. Babbitt Steam Specialty Co.
    b. Roto Hammer Industries.
    c. Trumbull Industries.
2. Description: Valve actuation assembly with sprocket rim, brackets, and chain.
    a. Brackets: Type, number, size, and fasteners required to mount actuator on valve.
    b. Attachment: For connection to ball, butterfly, and plug valve stems.
    c. Sprocket Rim with Chain Guides: Ductile or cast iron, of type and size required for valve.
    d. Chain: Hot-dip, galvanized steel, of size required to fit sprocket rim.

PART 3 - EXECUTION

3.1 VALVE APPLICATIONS

A. Refer to piping Sections for specific valve applications. If valve applications are not indicated, use the following:
1. Shutoff Service: Ball or butterfly.

2. Throttling Service: Ball or butterfly.
3. Pump Discharge: Ball or butterfly
4. Branch Line or Dead End Service: Butterfly Valve

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

C. Chilled-Water Piping: Use the following types of valves:
1. Ball Valves, NPS 2 and Smaller: Two-piece, 600-psig CWP rating, copper alloy.
2. Butterfly Valves, NPS 2-1/2 and Larger: Single-flange, 150-psig CWP rating, ferrous alloy.
3. Spring-Loaded, Lift-Disc Check Valves, NPS 2 and Smaller: Type IV, Class 125 minimum.
4. Spring-Loaded, Lift-Disc Check Valves, NPS 2-1/2 and Larger: Type Ill, Class 125, cast iron.

D. Condenser Water Piping: Use the following types of valves:
1. Ball Valves, NPS 2 and Smaller: Two-piece, 600-psig CWP rating, copper alloy.
2. Butterfly Valves, NPS 2-1/2 and Larger: Single-flange, 150-psig CWP rating, ferrous alloy.
3. Spring-Loaded, Lift-Disc Check Valves, NPS 2 and Smaller: Type IV, Class 125 minimum.
4. Spring-Loaded, Lift-Disc Check Valves, NPS 2-1/2 and Larger: Type Ill, Class 125, cast iron.

E. Select valves, except wafer and flangeless types, with the following end connections:
1. For Copper Tubing, NPS 2 and Smaller: Solder-joint or threaded ends
2. For Copper Tubing, NPS 2-1/2 to NPS 4: Flanged or threaded ends.
3. For Copper Tubing, NPS 5 and Larger: Flanged ends.
4. For Steel Piping, NPS 2 and Smaller: Threaded ends.
5. For Steel Piping, NPS 2-1/2 to NPS 4: Flanged or threaded ends.
6. For Steel Piping, NPS 5 and Larger: Flanged ends.

3.2 VALVE INSTALLATION

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown. [Exception: Unions and flanges may be omitted on valves installed with pre-approved grooved-mechanical-joint couplings, i.e. pipe connections to chillers]

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. Butterfly valves may be installed with stem horizontal to allow support for the disc and the cleaning action of the disc.

E. Install quarter-tum valves so handle in open position is downstream of valve.

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

G. Install chainwheels on operators for butterfly valves NPS 4 and larger and more than 96 inches above floor. Extend chains to 48 inches above finished floor.

H. Install check valves for proper direction of flow and as follows:
   1. Lift Check Valves: With stem upright and plumb.

3.3 JOINT CONSTRUCTION

A. Refer to Division 23 Section 23 05 15 "Common Work Results for HVAC" for basic piping joint construction.

B. Soldered Joints: Use ASTM B 813, water-flushable, lead-free flux; ASTM B 32, lead-free-alloy solder; and ASTM B 828 procedure, unless otherwise indicated.

C. Grooved Joints (pre-approved): Assemble joints with keyed coupling housing, gasket lubricant, and bolts, according to coupling and fitting manufacturer's written instructions.

3.4 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.

END OF SECTION

SECTION 23 05 29

HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following:
   1. Steel pipe hangers and supports.
   2. Metal framing systems.
   3. Thermal-hanger shield inserts.
   4. Fastener systems.
   5. Equipment supports.

B. Related Requirements:
   1. Section 05 43 00 “Slotted Channel Framing” and Section 05 50 00 “Metal Fabrications” for trapeze hangers for pipe and equipment supports.
   2. Division 21 for fire protection piping.
   3. Section 23 05 48 "Vibration Controls for HVAC Piping and Equipment" for vibration isolation devices.
   4. Section 23 31 13 "Metal Ducts” for duct hangers and supports.

1.2 REFERENCES

A. ASTM A653 G90 SS Gr. 33 – Specification for Steel Sheet, Zinc Coated (Galvanized) by the Hot Dipped Process

B. ASTM B633 – Specification for Electrodeposited Coatings of Zinc on Iron and Steel

C. ASTM C531 – Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical Resistant Mortars, Grouts, Monolithic Surfaces, and Polymer Concretes

D. ASTM C642 – Test Method for Specific Gravity, Absorption, and Voids in Hardened Concrete

E. ASTM C672 – Test Methods for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

F. ASTM D412 – Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension

G. ASTM D395 – Standard Test Methods for Rubber Property – Compression Set

H. ASTM D573 – Test Method for Rubber – Deterioration in an Air Oven

I. ASTM D746 – Test Method for Brightness Temperature of Plastics and Elastomers by Impact

J. ASTM D2240 – Test Method for Rubber Property – Durometer Hardness

K. NFPA 70 – National Electrical Code

1.3 DEFINITIONS

A. Terminology: As defined in MSS SP-90, "Guidelines on Terminology for Pipe Hangers and Supports."

1.4 ACTION SUBMITTALS

A. Product Data: For the following:
   1. Steel pipe hangers and supports.
   2. Metal framing systems.
   3. Thermal-hanger shield inserts.
   4. Powder-actuated fastener systems.

B. Shop Drawings, for the following:
   1. Pipe stand fabrication.
   2. Equipment support fabrication

1.5 INFORMATIONAL SUBMITTALS

A. Welding certificates.

1.6 QUALITY ASSURANCE

A. Welding: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

2.2 PERFORMANCE REQUIREMENTS

A. Design supports for multiple pipes capable of supporting combined weight of supported systems, system contents, and test water.

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

2.3 STEEL PIPE HANGERS AND SUPPORTS

A. Description: MSS SP-58, Types 1 through 58, factory-fabricated components. Refer to Part 3 "Hanger and Support Applications" Article for where to use specific hanger and support types.

B. Manufacturers:
   1. B-Line Systems, Inc.; a division of Cooper Industries.
   2. Carpenter & Paterson, Inc.
   3. ERICO/Michigan Hanger Co.
   4. Grinnell Corp.
   5. Tolco Inc.

C. Galvanized, Metanyic Coatings: Pregalvanized or hot dipped.

D. Nonmetallic Coatings: Plastic coating, jacket, or liner.

E. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion for support of bearing surface of piping.

2.4 TRAPEZE PIPE HANGERS

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

2.5 METAL FRAMING SYSTEMS

A. Description: MFMA-3, shop- or field-fabricated pipe-support assembly made of steel channels and other components.

B. Manufacturers:
   1. B-Line Systems, Inc.; a division of Cooper Industries.
   2. ERICO/Michigan Hanger Co.; ERISTRUT Div.
   3. Tolco Inc.
   4. Unistrut Corp.; Tyco International, Ltd.

C. Coatings: Manufacturer's standard finish unless bare metal surfaces are indicated.

D. Nonmetallic Coatings: Plastic coating, jacket, or liner.

2.6 THERMAL-HANGER SHIELD INSERTS

A. Description: 100-psig- minimum, compressive-strength insulation insert encased in sheet metal shield.

B. Manufacturers:
  1. Carpenter & Paterson, Inc.
  2. ERICO/Michigan Hanger Co.
  3. Pipe Shields, Inc.

C. Insulation-Insert Material for Cold Piping: Water-repellent treated, ASTM C 533, Type I calcium silicate or ASTM C 552, Type II cellular glass with vapor barrier.

D. Insulation-Insert Material for Hot Piping: Water-repellent treated, ASTM C 533, Type I calcium silicate or ASTM C 552, Type II cellular glass.

E. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.

F. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.

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

2.7 FASTENER SYSTEMS

A. Mechanical-Expansion Anchors: Insert-wedge-type zinc-coated or stainless steel, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
  1. Manufacturers:
  2. B-Line Systems, Inc.; a division of Cooper Industries.
    a. Empire Industries, Inc.
    b. Hilti, Inc.
    c. ITW Ramset/Red Head.
    d. MKT Fastening, LLC.
    e. Powers Fasteners.

2.8 EQUIPMENT SUPPORTS

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

2.9 PIPE STAND FABRICATION

A. Pipe Stands, General: Shop or field-fabricated assemblies made of manufactured corrosion-resistant components.

B. Compact Pipe Stand: One-piece plastic unit with integral-rod-roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.

1. Available Manufacturers:
   a. ERICO/Michigan Hanger Co.
   b. MIRO Industries.

C. Low-Type, Single-Pipe Stand: One-piece plastic or stainless-steel base unit with plastic roller, for roof installation without membrane penetration.

1. Available Manufacturers:
   a. MIRO Industries.

D. High-Type, Single-Pipe Stand: Assembly of base, vertical and horizontal members, and pipe support, for roof installation without membrane penetration.

1. Available Manufacturers:
   a. ERICO/Michigan Hanger Co.
   b. MIRO Industries.
   c. Portable Pipe Hangers.
2. Base: Stainless steel.
3. Vertical Members: Two or more cadmium-plated-steel or stainless-steel, continuous-thread rods.
4. Horizontal Member: Cadmium-plated-steel or stainless-steel rod with plastic or stainless-steel, roller-type pipe support.

E. High-Type, Multiple-Pipe Stand: Assembly of bases, vertical and horizontal members, and pipe supports, for roof installation without membrane penetration.

1. Available Manufacturers:
   a. Portable Pipe Hangers.
2. Bases: One or more plastic.
3. Vertical Members: Two or more protective-coated-steel channels.
4. Horizontal Member: Protective-coated-steel channel.
5. Pipe Supports: Galvanized-steel, clevis-type pipe hangers.

F. Curb-Mounting-Type Pipe Stands: Shop- or field-fabricated pipe support made from structural-steel shape, continuous-thread rods, and rollers for mounting on permanent stationary roof curb.

2.10 EQUIPMENT SUPPORTS

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

2.11 MISCELLANEOUS MATERIALS

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

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

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

2.12 ROOFTOP SUPPORTS FOR PIPING

A. Comparable to Eaton, B-Line, “DURA – BLOK” pipe support system.

B. Materials:

1. Curb base must be made of 100% recycled rubber and polyurethane prepolymer with a uniform load capacity of 500 pounds per linear foot of support.
2. Steel Frame: Steel, strut galvanized per ASTM A653 or strut galvanized per ASTM A653 for bridge series.
3. Attaching Hardware: Zinc-plated threaded rod, nuts and attaching hardware per ASTM B633.

C. Physical Performance Characteristics:

1. Density: 0.52 oz/cu in ASTM C642
2. Durometer Hardness: 67.2A + 1 ASTM D2240
3. Tensile Strength: 231 psi minimum ASTM D412
4. Compression Deformation: 5% at 70psi and 72ºF ASTM D395
5. Brittleness at Low Temp: -50ºF ASTM D746
6. Freeze and thaw when exposed to deicing chemicals: No loss after 50 cycles ASTM C672
7. Coefficient of Thermal Expansion: 8 x 10-6 in/inºF (min) ASTM C531
8. Weathering: 70 hours at 120ºF ASTM D573
   a. Hardness retained: 100% (+5%)
   b. Compressive Strength: 100% (+5%)
   c. Tensile strength: 100% (+5%)
   d. Elongation retained: 100 % (+5%)

D. Support System Components:

1. Rubber block supports – DURA-BLOKTM model # DBP or DMB base. Accessories are fastened directly into rubber material with weather resistant type 12 lag screws.
2. Continuous block channel supports – DURA-BLOKTM DB Series or DB6 Series. Assembly has 1” gaps between blocks for free flow of water. Standard strut accessories can be used for attachment.
3. Bridge channel supports – DURA-BLOKTM DB10 Series. Standard strut accessories can be used for attachment.
4. Extendible height supports – DURA-BLOKTM model DBE, height to suit application: 8-inch, 12-inch or 16-inch (200 pound maximum load). Base to be 9.6 inches in length or otherwise specified sizes available. Heavier loads, may require CLDP load distribution plate.

5. Roller Supports – DURE-BLOKTM DBR10 Series & DBR Series: DBR10 Series is sized for pipe up to 3 ½ inches, with vertical adjustment up to 12 inches.
6. Elevated single pipe supports – DURE-BLOKTM DBM Series: Copper or Steel.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT APPLICATIONS

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

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

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

D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.
   1. Contractor’s Option 1: Provide felt-lined pipe insulator or elastomeric pipe clamp cushion where ferrous attachments are in direct contact with copper tubing.
   2. Contractor’s Option 2: Wrap copper tubing with not less than two layers of 10 mil thick black plastic tape extending to a minimum of 1 inch on each side of clamp.

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

F. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
   1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated stationary pipes, NPS 1/2 to NPS 30.
   2. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes, NPS 3/4 to NPS 24, requiring clamp flexibility and up to 4 inches of insulation.
   3. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of noninsulated stationary pipes, NPS 1/2 to NPS 8.
   4. U-Bolts (MSS Type 24): For support of heavy pipes, NPS 1/2 to NPS 30.
   5. Pipe Saddle Supports (MSS Type 36): For support of pipes, NPS 4 to NPS 36, with steel pipe base stanchion support and cast-iron floor flange.
   6. Single Pipe Rolls (MSS Type 41): For suspension of pipes, NPS 1 to NPS 30, from 2 rods if longitudinal movement caused by expansion and contraction might occur.
   7. Complete Pipe Rolls (MSS Type 44): For support of pipes, NPS 2 to NPS 42, if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.

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

1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers, NPS 3/4 to NPS 20.
2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers, NPS 3/4 to NPS 20, if longer ends are required for riser clamps.

H. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.
2. Steel Clevises (MSS Type 14): For 120 to 450 deg F piping installations.

I. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
2. Top-Beam C-Clamps (MSS Type 19): For support of pipes to NPS4, under roof installations with bar-joist construction to attach to top flange of structural shape. Provide retaining strap.
3. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
4. C-Clamps (MSS Type 23): For support of pipes to NPS 4, attached to structural shapes. Provide retaining strap.
5. Welded-Steel Brackets: For support of pipes from below, or for suspending from above by using clip and rod. Use one of the following for indicated loads:
   a. Light (MSS Type 31): 750 lb.
   b. Medium (MSS Type 32): 1500 lb.
   c. Heavy (MSS Type 33): 3000 lb.
6. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.

J. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Steel Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
3. Thermal-Hanger Shield Inserts: For supporting insulated pipe.

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

L. Comply with MFMA-102 for metal framing system selections and applications that are not specified in piping system Sections.

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

N. Use trapeze pipe hangers or metal framing systems for groups of parallel pipes.

3.2 HANGER AND SUPPORT INSTALLATION

A. Steel Pipe Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from 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 mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions. Do not use in lightweight concrete or concrete slabs less than 4 inches thick.

E. Install hangers and supports complete with necessary 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, NPS 2-1/2 and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

J. Load Distribution: Install hangers and supports so 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 so maximum pipe deflections allowed by ASME B31.1 (for power piping) and ASME B31.9 (for building services piping) are not exceeded.

L. Insulated Piping: Comply with the following:

1. Attach clamps and spacers to piping.
    a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
    b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
    c. Do not exceed pipe stress limits according to ASME B31.1 for power piping and ASME B31.9 for building services piping.
2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.

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. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick.
   b. NPS 4: 12 inches long and 0.06 inch thick.
   c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick.
   d. NPS 8 to NPS 14: 24 inches long and 0.075 inch thick.
   e. NPS 16 to NPS 24: 24 inches long and 0.105 inch thick.
5. Pipes NPS 8 and Larger: Include wood inserts.
6. Insert Material: Length at least as long as protective shield.
7. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

3.3 EQUIPMENT SUPPORTS

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

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

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

3.4 METAL FABRICATIONS

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

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

C. Field Welding: Comply with AWS D1.1 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 contours of welded surfaces match adjacent contours.

3.5 ADJUSTING

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

3.6 ROOFTOP SUPPORTS FOR PIPING

A. Install in accordance with manufacturer’s instructions and recommendations.

B. If gravel top roof, gravel must be removed around and under pipe support.

C. Always consult roofing manufacturer for roof membrane compression capacities. If necessary, a compatible sheet of roofing material (rubber pad) may be installed under rooftop support to disperse concentrated loads and add further membrane protection.

D. Use properly sized clamps to suit pipe sizes.

3.7 PAINTING

A. Touch Up: 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 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.

END OF SECTION

SECTION 23 05 48

VIBRATION CONTROLS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Elastomeric Isolation pads.
   2. Elastomeric Isolation mounts.
   3. Freestanding and restrained spring isolators.
   4. Elastomeric hangers.
   5. Spring hangers.
   6. Spring hangers with vertical-limit stops.
   7. Pipe riser resilient supports.
   8. Resilient pipe guides.

1.2 ACTION SUBMITTALS

A. Product Data: For each product indicated. Include load deflection curves.
   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 device type required.

B. Shop Drawings:
   1. Detail fabrication and assembly of equipment bases.
      a. Detail fabrication including anchorages and attachments to structure and to supported equipment.
      b. Include adjustable motor bases, rails, and frames for equipment mounting.
   2. Vibration Isolation Base Details:
      a. Detail fabrication including anchorages and attachments to structure and to supported equipment.
      b. Include adjustable motor bases, rails, and frames for equipment mounting.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Show coordination of vibration isolation device installation for HVAC piping and equipment with other systems and equipment in the vicinity, including other supports and restraints, if any.

B. Qualification Data: For testing agency.

C. Welding certificates.

D. Air-Mounting System Performance Certification: Include natural frequency, load, and damping test data for factory tests.

1.4 CLOSEOUT SUBMITTALS

A. Operations and Maintenance Data: To include in operation and maintenance manuals.

1.5 QUALITY ASSURANCE

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

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Wind Restraint Loading:
1. Basic Wind Speed: As per project site.
2. Building Classification Category: As per project site.
3. Minimum 10 lb/sq. ft. multiplied by the maximum area of the HVAC component projected on a vertical plane that is normal to the wind direction, and 45 degrees either side of normal.

2.2 VIBRATION ISOLATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Ace Mountings Co., Inc.
2. Amber/Booth Company, Inc.
3. California Dynamics Corporation.
4. Isolation Technology, Inc.
5. Kinetics Noise Control.
6. Mason Industries.
7. Vibration Eliminator Co., Inc.
8. Vibration Isolation.
9. Vibration Mountings & Controls, Inc.

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

2. Fabrication: Single or multiple layers of sufficient durometer stiffness for uniform loading over pad area.
3. Size: Factory or field cut to match requirements of supported equipment.
4. Pad Material: Oil and water resistant with elastomeric properties.
5. Surface Pattern: Ribbed or Waffle pattern.
6. Infused nonwoven cotton or synthetic fibers.

C. Elastomeric Isolation Mounts: Double-deflection type, with molded, oil-resistant, neoprene isolator elements with factory-drilled, encapsulated top plate for bolting to equipment and with baseplate for bolting to structure. Color-code or otherwise identify to indicate capacity range.
1. Materials: Cast-ductile-iron or welded steel housing containing two separate and opposing, oil-resistant neoprene elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.
2. Neoprene: Shock-absorbing materials compounded according to the standard for bridge-bearing neoprene as defined by AASHTO.

D. Spring Isolators: Freestanding, laterally stable, open-spring isolators.
1. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
2. Minimum Additional Travel: 50 percent of the required deflection at rated load.
3. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
4. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
5. Baseplates: Factory drilled for bolting to structure and bonded to 1/4-inch- thick, rubber isolator pad attached to baseplate 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.

E. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with limit-stop restraint.
1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to weight being removed; factory-drilled baseplate bonded to 1/4-inch- thick, neoprene isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.
2. Restraint: Limit stop as required for equipment.
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.

F. Elastomeric Hangers: Single or double-deflection type with threaded connections for Upper and Lower Steel Hanger Rods. Color-code or otherwise identify to indicate capacity range.

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.

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

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

H. Spring Hangers with Vertical-Limit Stop: Combination coil-spring and elastomeric- insert hanger with spring and insert in compression and with a vertical-limit stop.

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 neoprene.
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.

I. 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 equipment.

1. Frame: Steel, fabricated for connection to threaded rods and to allow for a maximum of 30 degrees of angular 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 neoprene.
7. Coil Spring: Factory set and field adjustable for a maximum of 1/4-inch movement at start and stop.

J. Pipe Riser Resilient Support: All-directional, acoustical pipe anchor consisting of 2 steel tubes separated by a minimum of 1/2-inch- thick neoprene. Include steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions. Design support for a maximum load on the isolation material of 500 psig and for equal resistance in all directions.

K. Resilient Pipe Guides: Telescopic arrangement of 2 steel tubes or post and sleeve arrangement separated by a minimum of 1/2-inch- thick neoprene. Where clearances are not readily visible, a factory-set guide height with a shear pin to allow vertical motion due to pipe expansion and contraction shall be fitted. Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

2.3 VIBRATION ISOLATION EQUIPMENT BASES

A. Steel Rails: Factory-fabricated, welded, structural-steel rails.
   1. Design Requirements: Lowest possible mounting height with not less than 1-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide rails.
   2. Include supports for suction and discharge elbows for pumps.
   3. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Rails shall have shape to accommodate supported equipment.
   4. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

B. Steel Bases: Factory-fabricated, welded, structural-steel bases and rails.
   1. Design Requirements: Lowest possible mounting height with not less than 1-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.
   2. Include supports for suction and discharge elbows for pumps.
   3. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.

4. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.

C. Concrete Inertia Base: Factory-fabricated, welded, structural-steel bases and rails ready for placement of cast-in-place concrete.
   1. Design Requirements: Lowest possible mounting height with not less than 1-inch clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.
   2. Include supports for suction and discharge elbows for pumps.
   3. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.
   4. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.
   5. Fabrication: Fabricate steel templates to hold equipment anchor-bolt sleeves and anchors in place during placement of concrete. Obtain anchor-bolt templates from supported equipment manufacturer.

D. Restrained Isolation Roof-Curb Rails:
   1. Description: Factory-assembled, fully enclosed, insulated, air- and watertight curb rail designed to resiliently support equipment.
   2. Upper Frame: Upper frame shall provide continuous and captive support for equipment.
   3. Lower Support Assembly: The lower support assembly shall be formed sheet metal section containing adjustable and removable steel springs that support upper frame. The lower support assembly shall have a means for attaching to building structure and a wood nailer for attaching roof materials and shall be insulated with a minimum of 2 inches of rigid glass-fiber insulation on inside of assembly. Adjustable, restrained-spring isolators shall be mounted on elastomeric vibration isolation pads and shall have access ports, for level adjustment, with removable waterproof covers at all isolator locations. Isolators shall be located so they are accessible for adjustment at any time during the life of the installation without interfering with the integrity of the roof.
   4. Snubber Bushings: All-directional, elastomeric snubber bushings at least 1/4 inch thick.
   5. Water Seal: Galvanized sheet metal with EPDM seals at corners, attached to upper support frame, extending down past wood nailer of lower support assembly, and counterflashed over roof materials.

E. Flexible Hoses:
   1. Fan coil units, water source heat pump units.
      a. Flexible stainless steel hose shall have stainless steel braid and carbon steel fittings. Sizes 3” and larger shall be flanged. Smaller sizes shall have male nipples.
      b. Hoses shall be installed on piping connections to designated equipment, on the equipment side of the shutoff valves horizontally and parallel to the equipment shafts wherever possible.

c. As an alternate to flexible hoses, for piping 2 ½” and larger, provide (3) flexible grooved couplings, in series.

d. Hoses shall be upsized from equipment connection sizes to limit total pressure drop of hose and valves to less than 5 psi at full flow. Submit total pressure drop calculations at design conditions.

F. Flexible Connectors:

1. Cooling Towers, Fluid Coolers, Exterior Air Handling Units:

a. 304 stainless steel braid bands, hose, and braid, with carbon steel fixed and floating flanges.

G. Pump Connectors:

1. Rubber expansion joints shall be peroxide cured EDPM throughout with Kevlar tire cord reinforcement. Substitutions must have certifiable equal or superior characteristics. The raised face rubber flanges must encase solid steel rings to prevent pull out. Flexible cable wire is not acceptable. Sizes 1-1/2” through 14” shall have a ductile iron external ring between the two spheres.

2. Minimum ratings through 14” shall be 250 psi at 170°F and 215 psi at 250°F.

3. Safety factors shall be a minimum of 3/1. All expansion joints must be factory tested to 150% of maximum pressure for 12 minutes before shipment.

4. The piping gap shall be equal to the length of the expansion joint under pressure. Control rods passing through ½” thick Neoprene washer bushings large enough to take the thrust at 1000 psi of surface area may be used on unanchored piping where the manufacturer determines the condition exceeds the expansion joint rating without them. Submittals shall include two test reports by independent consultants showing minimum reductions of 20 DB in vibration accelerations and 10 DB in sound pressure levels at typical blade passage frequencies on this or a similar product by the same manufacturer. All expansion joints shall be installed on the equipment side of the shut off valves. Expansion joints shall be SAFEFLEX SFDEJ, SFEJ, SFDCR or SFU and Control Rods CR as manufactured by Mason Industries, Inc.

5. Any connectors exposed to sunlight shall be stainless steel listed for use intended.

6. Provide a metal cover over the connectors, to limit direct sunlight on the connectors; and which shall not limit the connector flexibility. Cover shall be permanent. Submit a shop drawing with the proposal cover detail.

PART 3 - EXECUTION

3.1 APPLICATION

A. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits.

3.2 EXAMINATION

A. Examine areas and equipment to receive vibration isolation 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.

3.3 VIBRATION CONTROL DEVICE INSTALLATION

A. Comply with requirements in Division 07 for installation of roof curbs, equipment supports, and roof penetrations.

B. All vibration isolators must be installed in strict accordance with the manufacturers written instructions and all certified submittal data.

C. Equipment Restraints:
1. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.
2. Install thrust limits at centerline of thrust, symmetrical on either side of equipment.

D. 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.

E. Drilled-in Anchors:
1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Set anchors to manufacturer's recommended torque, using a torque wrench.
5. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

F. Coordinate the location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork.

G. Installation of vibration isolators must not cause any change of position of equipment, piping, or ductwork resulting in stresses or misalignment.

H. No rigid connections between equipment and the building structure shall be made that degrades the noise and vibration control system herein specified.

I. Coordinate work with other trades to avoid rigid contact with the building.

J. Any conflicts with other trades which will result in rigid contact with equipment or piping due to inadequate space or other unforeseen conditions should be brought to the architects/engineer's attention prior to installation. Corrective work necessitated by conflicts after installation shall be at the responsible contractor's expense.

K. Flexible Pipe Connectors: Install on equipment side of shutoff valves, horizontally and parallel to equipment shafts wherever possible.

3.4 VIBRATION ISOLATION EQUIPMENT BASES INSTALLATION

A. Coordinate the location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork.

3.5 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.

C. Adjust thrust limits to a maximum of 1/4-inch movement during start and stop.

D. Adjust active height of spring isolators.

E. Adjust restraints to permit free movement of equipment within normal mode of operation.

END OF SECTION

SECTION 23 05 53

IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
1. Equipment labels.
2. Warning signs and labels.
3. Pipe labels.
4. Duct labels.
5. Valve tags.
6. Refrigeration Machinery Room identification.

1.2 ACRONYMS

A. The following are used throughout this Section:

1.	AUTO	Automatic Control
2.	MAN	Manual Control
3.	CHL	Chiller
4.	PLNT	Central Plant
5.	CHM	Chemical Treatment System
6.	PMPX	Pump (X=number)
7.	COND	Condenser Water Loop
8.	PRI	Primary Chilled Water Loop
9.	CTW	Cooling Tower
10.	SEC	Secondary Chilled Water Loop
11.	EQ	Equalizing Line
12.	SEP	Centrifugal Separator
13.	FC	Fan Coil
14.	VLV	Valve
15.	HX	Heat Exchanger
16.	(X)-PLNT	(Number)-Plant

1.3 ACTION SUBMITTALS

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

B. Valve Schedule: Furnish a complete electronic version of valve schedule.

1.4 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: Include copy of Valve Schedule in O&M Manual.

B. Record Drawings:
1. Provide an as-built system piping diagram drawing that shows the major equipment and valves with Valve ID for review prior to mounting.
2. Provide an annotated as-built floor plan drawing that shows the major equipment and valves with Valve ID for review prior to mounting.

PART 2 - PRODUCTS

2.1 EQUIPMENT LABELS

A. Metal Labels for Equipment:
1. Material and Thickness: Black anodized aluminum for mechanical engraving, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.
2. Minimum Label Size: Length and width vary, but not less than 2-1/2 by 3/4 inch.
3. Minimum Letter Size: 1 inch.
4. Fasteners: Stainless-steel rivets or self-tapping screws.
5. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

B. Plastic Label for Equipment:
1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.
2. Letter Color: White.
3. Background Color: Black.
4. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
6. Minimum Letter Size: 1 inch.
7. Fasteners: Stainless-steel rivets or self-tapping screws.
8. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

C. Label Content: Include equipment's Drawing designation or unique equipment number as directed by Owner.

2.2 WARNING SIGNS AND LABELS

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

B. Letter Color: White.

C. Background Color: Red.

D. Maximum Temperature: Able to withstand temperatures up to 160 deg F.

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

F. Minimum Letter Size: 1 inch main lettering, 3/4 inch secondary lettering.

G. Fasteners: Stainless-steel rivets or self-tapping screws.

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

I. Label Content: Include caution and warning information, plus emergency notification instructions as indicated on drawings and specifications.

2.3 PIPE COLORS

A. Paint HVAC water pipe with Johns Manville Zeston 2000 Series Paint as required below.
1. Chilled Water Supply: Blue
2. Chilled Water Return: Light Blue
3. Condenser Water Inside Plant: Green
4. Condenser Water Outside Plant: Pea Green

2.4 PIPE LABELS

A. General Requirements for Manufactured Pipe Labels: Comply with ANSI Standard A13.1-2007 for lettering and background colors.

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

C. Rigid Carrier Pipe Labels: Use only MS-995 Maxilar™ Rigid Carrier Pipe Markers strapped to pipe with Type 316 ss banding.

D. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings, and an arrow indicating flow direction.
1. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions or as separate unit on each pipe label to indicate flow direction.
2. Lettering Size(minimum):
3. Pipe: <2.5" Letters: 3/4" high Pipe: 2.5 Ð 6" Letters: 1.5" high
4. Pipe: 8-10" Letters: 2.5" high Pipe: >10" Letters: 3.5" high

E. Outdoor grade vinyl film printed using UV and chemical resistant inks, 3mils thick.

F. Provided with directional arrow for direction.

G. Solvent based adhesive backing.

H. Minimum size is 16” x 2-1/4” with 1-1/2” letters.

I. Color coding per approved submittal.

2.5 VALVE TAGS

A. Valve Tags: Stamped or engraved, minimum 2-inch size Include 1-inch identifying number. Provide 5/32-inch hole for fastener.

1. Material: 0.032-inch-thick brass.
2. Valve-Tag Fasteners: Brass wire-link or beaded chain; or S-hook.

PART 3 - EXECUTION

3.1 PREPARATION

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

3.2 EQUIPMENT LABEL INSTANUATION

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

B. Locate equipment labels where accessible and visible.

C. Label equipment above ceilings so that labels are accessible and visible through equipment access points.

3.3 PIPE LABEL INSTALLATION

A. Install manufactured pipe markers indicating service on each piping system. Install with flow indication arrows showing direction of flow.

1. Pipe OD, incl. Insulation, Less Than 6 Inches: Pre-tensioned pipe markers.
2. Pipe OD, incl. Insulation, 6 Inches and Larger: MS-995 Maxilar™ Rigid Carrier Pipe Markers

B. 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 20 feet along each run. Reduce intervals to 10 feet in areas of congested piping and equipment.

3.4 DUCT LABEL INSTALLATION

A. Install manufactured duct markers indicating service on each duct as indicated on the construction drawings. Install with flow indication arrows showing direction of flow.

3.5 VALVE TAG INSTALLATION

A. Install tags on valves and control devices in piping systems including piping within refrigeration machinery rooms, boiler rooms, mechanical equipment room, mechanical equipment yards, piping mains, and piping branches serving more than one piece of equipment. Tags are not required on check valves; valves within factory-fabricated equipment units; and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units.

B. Identify tagged valves as follows
   1. Number: e.g. 1, 2, 3

3.6 VALVE SCHEDULE

A. Provide a Valve Schedule in spreadsheet or table form. Valve schedule shall indicate the following:
   1. System: e.g., SEC, COND, CHW, CTW-1, CHL-B2
   2. Subsystem: e.g. PMP-B2, COND,
   3. Component: e.g. VLV, FC
   4. Number: e.g. 1, 2, 3
   5. Mode of Operation: e.g. Auto, Man, A/M
   6. Default Position: NO or NC.
   7. Description (Function): e.g., Cooling Tower B2 By-Pass Valve
   8. Location: e.g., "Above ceiling in Corridor C-01 near Room 117."

B. Mount valve schedule under plastic in main mechanical room, or elsewhere as directed by Owner.

3.7 AS BUILT MECHANICAL “FLOOR PLAN” DRAWING UNDER PLASTIC

A. Place this under plastic next to the Valve Schedule.

3.8 AS-BUILT MECHANICAL "PIPING DIAGRAM" DRAWING UNDER PLASTIC

A. Place this under plastic next to the Valve Schedule.

3.9 REFRIGERATION MACHINERY ROOM INDENTIFICATION

A. Mount general information placard on wall in refrigeration machinery room adjacent to main entry.

B. Securely mount control device labels adjacent to each control device.

3.10 ADJUSTING AND CLEANING

A. Relocate mechanical identification materials and devices that have become visually blocked by other work.

B. Clean faces or mechanical identification devices and glass frames of valve schedules.

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) to produce design objectives for the following:
   1. Air Systems:
      a. Constant-volume air systems.
      b. Variable-air-volume systems.
      c. Medium Pressure Duct Leakage Testing
   2. Hydronic Piping Systems
      a. Constant flow systems.
      b. Variable flow systems.
   3. HVAC equipment quantitative-performance settings.
   4. Kitchen hood airflow balancing.
   5. Existing systems TAB.
   6. Verifying that duct-mounted smoke detectors, smoke dampers, combination fire/smoke dampers are installed per the manufacturer's instructions and are operating correctly.
   7. Witnessing and Certifying the Operational Test of the Refrigerant Monitoring System.
   8. Assisting CxA, controls and mechanical contractor during commissioning. Refer to commissioning specifications.
   9. Reporting results of activities and procedures specified in this Section.

B. The firm that provides TAB services shall be under contract directly with the General Contractor and shall not be a subcontractor to the Mechanical Contractor, nor an affiliate of the Mechanical Contractor.

C. Provide supervision, personnel, instruments, calibration equipment, and other materials and services necessary to perform testing and balancing of the heating, ventilating and air conditioning systems. Test data including all pertinent calculations shall be reported on appropriate forms.

D. Coordinate with the BMS contractor and provide and record required setpoints for system programming, which have been determined by testing and balancing.

E. The tests shall demonstrate the specified capacities and operation of equipment and materials comprising the systems.

1.2 DEFINITIONS

A. AABC: Associated Air Balance Council.

B. AMCA: Air Movement and Control Association.

C. CTI: Cooling Tower Institute.

D. NEBB: National Environmental Balancing Bureau.

E. SMACNA: Sheet Metal and Air Conditioning Contractors' National Association.

F. TAB: Testing, Adjusting, and Balancing.

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

1.3 SUBMITTALS

A. Provide a list of the persons providing the services, their roles, and their certifications.

B. Provide samples of the report data forms to be included in the reports.

C. Provide a detailed diversity testing plan for variable air volume systems per 3.8.A.

1.4 QUALITY ASSURANCE

A. TAB Firm Qualifications: Engage a TAB firm certified by AABC or NEBB.

B. Comply with applicable procedures and standards of the certification sponsoring association, either:
   1. "National Standards for Field Measurements and Instrumentation, Total System Balance, Air Distribution-Hydronics System" by AABC.
   2. ASHRAE standards.
   3. "Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems" by NEBB.
   4. Work onsite shall be performed under direction of the Site Supervisor who is designated and qualified under certification requirements of sponsoring association.
   5. Calibration and maintenance of instruments shall be in accordance with requirements of the standards, and calibration histories for each instrument shall be available for examination.
   6. Accuracy of measurements shall comply with requirements of the standards.

C. Approved TAB firms: Contact the Owner for the current list of approved firms.

D. The test and balance agency shall thoroughly review all contract documents, including the "Sequence of Operation". When their review has been completed, they shall identify issues which could have implications on their achieving the required system performance and the design values; and that they understand aspects of the systems design, and there are no issues which will affect their ability to perform their services and achieve the desired systems operation.

E. Certification of TAB Reports: Certify TAB field data reports. This certification includes the following:
   1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
   2. Certify that TAB team complied with approved TAB plan and the procedures specified and referenced in this Specification.

F. TAB Reports: Use standard forms from AABC's "National Standards for Testing, Adjusting, and Balancing " or NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems".

G. Instrumentation Type, Quantity, and Accuracy: As described in AABC national standards or NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems," Section II, "Required Instrumentation for NEBB Certification".

H. Instrumentation Calibration: Calibrate instruments at least every six months or more frequently if required by the instrument manufacturer.

1.5 PROJECT CONDITIONS

A. Partial Owner Occupancy: Owner may occupy areas served by the systems partially under construction or completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

1.6 COORDINATION

A. Coordinate the efforts of factory-authorized service representatives for systems and equipment, HVAC controls installers, and other mechanics to operate HVAC systems and equipment to support and assist TAB activities.

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

1.7 WARRANTY

A. Special Guarantee: Provide a guarantee on AABC, NEBB, or TABB forms stating that AABC, NEBB, or TABB will assist in completing the requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Guarantee includes the following provisions:
   1. The certified TAB firm has tested and balanced systems according to the Contract Documents.
   2. Systems are balanced to optimum performance capabilities within design and installation limits.

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.

1. Verify that air balancing devices, such as manual volume dampers, are required by the Contract Documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.
2. Verify that hydronic balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, and balancing valves, are required by the Contract Documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.

B. Examine approved submittal data of HVAC systems and equipment.

C. Examine Project Record Documents described in Division 01 Section 01 78 39 "Project Record Documents."

D. Examine air-systems equipment performance data including fan curves. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in or part of a system. Calculate system effect factors to reduce performance ratings of HVAC air-systems equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," Sections 7 through 10; or in SMACNA's "HVAC Systems-- Duct Design," Sections 5 and 6. Compare this data with the design data and installed conditions.

E. Examine hydronic equipment performance data including pump curves. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in or part of a system. Calculate system effect factors to reduce performance ratings of HVAC hydronic equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. Compare this data with the design data and installed conditions.

F. Examine system and equipment installations to verify that they are complete and that testing, cleaning, adjusting, and start-up specified in individual Sections have been performed.

G. Examine system and equipment test reports.

H. Examine HVAC air systems and equipment installations to verify that indicated balancing devices, such as manual volume dampers, are properly installed, and that their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

I. Examine HVAC hydronic system and equipment installations to verify that indicated balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, and balancing valves, are properly installed, and that their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

J. Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing and include them in the report(s).

K. Examine HVAC equipment to ensure that clean filters have been installed, bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

L. Examine equipment fan coil units, terminal units, such as variable-air-volume boxes, to verify that they are accessible, and their controls are connected and functioning.

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

N. Examine strainers for clean screens and proper perforations.

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

P. Examine equipment for installation and for properly operating safety interlocks and controls.

Q. Examine Smoke Control Devices:
   1. Duct mounted smoke detectors:
      a. Verify sensor length and mounting location is per the manufacturer’s instructions.
      b. Verify the detector is installed per the manufacturer’s instructions.
      c. Verify the velocity of the air in the duct at the sensor tube location is within the manufacturer’s recommended range.
      d. Verify pressure drop across the detector is within the manufacturer’s recommended range.
   2. Smoke dampers and combination fire/smoke dampers:
      a. Verify the dampers are installed per the manufacturer’s instructions.
      b. Verify that power and control wiring has been connected to the damper per the manufacturer’s instructions.
      c. Verify the damper opens and closes smoothly and completely.

R. Report deficiencies to the Engineer and Contractor before proceeding with the TAB procedures.

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

3.2 PREPARATION

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

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

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

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems", NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems", or TABB’s “HVAC Systems-Testing, Adjusting, and Balancing” and this Section.

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed. Restore vapor barrier and finish according to insulation Specifications for this Project.

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

D. Close or plug probe holes and test ports after testing and balancing.

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

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

D. Check airflow patterns from the outside-air louvers and dampers and the return- and exhaust-air dampers, through the supply-fan discharge and mixing dampers.

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

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

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

H. Check for airflow blockages.

I. Check condensate drains for proper connections and functioning.

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

K. Check for proper sealing of air duct system.

3.5 MEDIUM PRESSURE DUCT LEAKAGE TESTING

A. Test and balance contractor shall test ductwork systems designed to operate at static pressures in excess of 3 inches w.g. Ductwork systems and plenums shall be leak-tested in accordance with SMACNA HVAC Air Duct Leakage Test Manual with the rate of air leakage (CL) less than or equal to 6.0 as determined in accordance with the following equation.
   1. CL=F x P^0.65 where:
      a. F = the measured leakage rate in cfm per 100 square feet of duct surface
      b. P = the static pressure of the test.

B. At least 25 percent of the duct area shall be tested, and tested sections shall meet the requirements of the SMACNA HVAC Air Duct Leakage Test Manual.

C. Taps for VAV boxes and runouts to where the flex duct is to be installed shall be installed prior to testing. Seal runouts prior to testing.

D. Submit proposed sections for testing to the design engineer for approval prior to testing.

E. Once testing is complete, submit a report outlining the findings of the testing. The report shall be sealed by the engineer supervising the Test and Balance.

3.6 SMOKE DETECTOR TESTING

A. Test duct mounted smoke detectors and associated unit shutdowns and damper actuation in accordance with required special inspection procedures and IMC requirements.

B. Retest as required until systems operate as required and designed.

C. Provide a final report sealed by a registered professional engineer indicating required flow rates, differential pressures, velocities, and results.

3.7 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

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

1. Measure fan static pressures to determine actual static pressure as follows:
    a. Measure outlet static pressure as far downstream from the fan as practicable and upstream from restrictions in ducts such as elbows and transitions.
    b. Measure static pressure directly at the fan outlet or through the flexible connection.
    c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from 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.
    e. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.
    f. Simulate dirty filter operation and record the point at which maintenance personnel must change filters.
2. Measure static pressures entering and leaving other devices such as sound traps, heat recovery equipment, and air washers, under final balanced conditions.
3. Compare design data with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur. Recommend corrective action to align design and actual conditions.
4. Adjust fan speed using adjustable pulleys, VFD’s, or other motor speed control devices, where provided, to achieve design airflows.
5. If equipment modifications are required, e.g., sheave changes to adjust fan speed, obtain approval from Architect prior to making such modifications. Recommend adjustments to pulley sizes, motor sizes, and electrical connections to accommodate fan-speed changes.
6. 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 other operating modes to determine the maximum required brake horsepower.

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

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

C. Measure terminal 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 terminal outlets and inlets for each space to indicated airflows within specified tolerances of indicated values.

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

3.8 PROCEDURES FOR VARIABLE AIR VOLUME SYSTEMS

A. Compensating for Diversity: When the total airflow of terminal units is more than the indicated airflow of the fan, provide a detailed plan for review via the submittal process. The technician will place a selected number of terminal units at a maximum set-point 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 outside-air dampers at minimum, and 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 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 as described for constant-volume air systems.
5. Set terminal units at minimum cooling airflow and adjust controller or regulator to deliver the designed minimum cooling airflow. Check air outlets for a proportional reduction in airflow as described for constant-volume air systems.
   a. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.
6. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets 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. If this static pressure setpoint exceeds 1.2 inches w.c., report this to the Contractor and the Engineer of Record. Coordinate the relocation and/or addition of static pressure sensors with the project team to comply with the associated requirements of the International Energy Conservation Code.
8. Record the final fan performance data.

3.9 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 approved pump flow rate. Correct variations that exceed plus or minus 5 percent.

B. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:
1. Open manual valves for maximum flow.
2. Check rating of system relief valve(s).
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 and report this issue to the Contractor and the Engineer of Record.
8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.10 PROCEDURES FOR HYDRONIC SYSTEMS

A. Measure water flow at pumps. Use the following procedures, except for positive-displacement pumps:
1. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
2. Check system resistance. With valves open, read pressure differential across the pump and mark pump manufacturer's head-capacity curve. If the indicated flow rate is more than 10 percent above or 5% below the design flow rate, report this issue to the Contractor and Engineer of Record to pursue a change to the pump impeller. Adjust pump discharge valve until indicated water flow is achieved.

3. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.

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

C. Measure flow at stations and adjust, where necessary, to obtain first balance.
1. System components that have Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.

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

E. Adjust balancing stations to within specified tolerances of indicated flow rate as follows:
1. Determine the balancing station with the highest percentage over indicated flow.
2. Adjust each station in turn, beginning with the station with the highest percentage over indicated flow and proceeding to the station with the lowest percentage over indicated flow.
3. Record settings and mark balancing devices.

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

G. Measure the differential-pressure control valve settings existing at the conclusions of balancing.

3.11 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

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

3.12 PROCEDURES FOR MOTORS

A. Motors, 1/6 HP and Larger: Test at final balanced conditions and record the following data:
1. Manufacturer.
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 bypass for the controller to prove proper operation. Record observations, including controller manufacturer, model and serial numbers, and nameplate data.

3.13 PROCEDURES FOR CHILLERS

A. Balance water flow through each evaporator and condenser to within specified tolerances of indicated flow with 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. If water-cooled chillers, condenser-water entering and leaving temperatures, pressure drop, and water flow.
3. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
4. Power factor if factory-installed instrumentation is furnished for measuring kilowatt.
5. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatt.
6. Capacity: Calculate in tons of cooling.
7. If air-cooled chillers, verify condenser fan rotation and record fan and motor data including number of fans and condenser entering- and leaving-air temperatures.

3.14 PROCEDURES FOR COOLING TOWERS

A. Balance condenser-water flow to each tower cell. Adjust make-up water level control device. Verify that makeup and blowdown systems are fully operational after tests and before leaving the equipment. Measure and record the following data for each cooling tower:
1. Condenser-water flow to each cell of the cooling tower.
2. Entering- and leaving-water temperatures.
3. Wet- and dry-bulb temperatures of entering air.
4. Wet- and dry-bulb temperatures of leaving air.
5. Tower-water flow rate recirculating through closed-circuit cooling towers.
6. Pump discharge pressure on closed-circuit cooling towers.
7. Adjust water level and feed rate of makeup-water system.

3.15 PROCEDURES FOR CONDENSING/OUTDOOR UNITS

A. Verify proper rotation of fans.

B. Measure entering- and leaving-air temperatures.

C. Record compressor and fan motor data.

3.16 PROCEDURES FOR ELECTRIC HUMIDIFIERS

A. Record nameplate and measured voltage, each phase, under full load conditions.

B. Record nameplate and measured amperage, each phase, under full load conditions.

C. Verify operation of blower, if equipped.

D. Verify operation of makeup water and blowdown valves.

3.17 PROCEDURES FOR HEAT-TRANSFER COILS

A. Water Coils: Measure and record the following data for each 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.

B. Electric-Heating Coils: Measure and record the following data for each coil:
   1. Airflow-Maximum.
   2. Airflow-Minimum.
   3. Entering- and leaving-air temperature at full load.
   4. Nameplate voltage and amperage input of each phase.
   5. Voltage and amperage input of each phase at full load and at each incremental stage.
   6. Calculated kilowatt at full load.
   7. Fuse or circuit-breaker rating for overload protection.

C. Refrigerant Coils: Measure and record the following data for each 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 PROCEDURES FOR HEAT-EXCHANGERS

A. Water to Water: Measure and record the following data for each side of the heat exchanger:
   1. Entering- and leaving-water temperature.
   2. Water flow rate.

3. Water pressure drop.

3.19 PROCEDURES FOR TEMPERATURE MEASUREMENTS

A. During TAB, report the need for adjustment in temperature regulation within the automatic temperature-control system.

B. Measure outside-air, wet- and dry-bulb temperatures.

3.20 PROCEDURES FOR COMMERCIAL KITCHEN HOODS

A. Test grease duct using light test procedure per International Mechanical Code requirements.

B. Measure, adjust, and record the airflow of each kitchen hood. For kitchen hoods designed with integral makeup air, measure and adjust the exhaust and makeup airflow. Measure airflow by duct Pitot-tube traverse. If a duct Pitot-tube traverse is not possible, provide an explanation in the report of the reason(s) why and the reason why the method used was chosen.
   1. Install welded test ports in the sides of the exhaust duct for the duct Pitot-tube traverse. Install each test port with a threaded cap that is liquid tight.

C. After balancing is complete, do the following:
   1. Measure and record the static pressure at the hood exhaust-duct connection.
   2. Measure and record the hood face velocity. Make measurements at multiple points across the face of the hood. Perform measurements at a maximum of 12 inches between points and between point and the perimeter. Calculate the average of the measurements recorded. Verify that the hood average face velocity complies with the Contract Documents and governing codes.
   3. Check the hood for capture and containment of smoke using a smoke emitting device. Observe the smoke pattern. Make adjustments to room airflow patterns to achieve optimum results.

D. Report deficiencies.

3.21 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

A. Before performing testing and balancing of existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished.
   1. New filters are installed.
   2. Coils are clean and fins combed.
   3. Drain pans are clean.
   4. Fans are clean.
   5. Bearings and other parts are properly lubricated.
   6. Strainers are clean.
   7. Deficiencies noted in the preconstruction report are corrected.

B. Perform testing and balancing of existing systems as directed in preceding Articles.

3.22 PROCEDURES FOR TESTING SMOKE CONTROL DEVICES

A. Record manufacturer and model number for each smoke detector, smoke damper, combination fire/smoke damper, and damper actuator.

B. Duct Mounted Smoke Detectors:

1. Verify the proper operation of the smoke detector using a test gas, “canned smoke”, acceptable to the Authorities Having Jurisdiction. (Magnets are not acceptable.)
2. Verify activation of the smoke detector closes the appropriate smoke or combination fire/smoke damper and/or de-energizes the appropriate air-moving device(s).
3. Verify activation of the smoke detector is shown by the fire alarm system where monitoring of the detector is required.

C. Smoke and Combination Fire/Smoke Dampers: Verify dampers controlled by a Total Coverage Smoke Detection System operate correctly on a signal from the system.

D. Air-Moving Device Shut-down: Verify air-moving device(s) that are to be de-energized by a Total Coverage Smoke Detection System de-energize on a signal from the system.

E. After smoke control devices have been installed, the TAB firm shall engage the services of a Professional Mechanical Engineer, registered in the State of Arizona, to witness the operation of each smoke control device and air-moving device shut-down. The Professional Mechanical Engineer shall submit a signed and sealed report attesting to the proper operation of the smoke control devices and air-moving device shut-downs.

3.23 PROCEDURES FOR TESTING REFRIGERANT MONITORS

A. Witness the Operational Test of the refrigerant monitor.

B. Verify the system performs the actions listed in the Sequence of Control. Confirm the outdoor air sensor is installed outside or in a location the monitor will calibrate a true zero condition. Perform the appropriate test and balance procedures on the exhaust system while in alarm mode.

C. Provide a signed statement on company letterhead in the Certified TAB Report that the Operational Test was completed successfully. Include the following:

1. Name and company of person conducting the test.
2. Time and date of the test(s).
3. Concentrations and type of refrigerant used.
4. Statement that the test was completed, and the system operates as specified.
5. Name and signature of witness.

3.24 TOLERANCES

A. Set HVAC system airflow and water flow rates within the following tolerances:
   1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus 10 to minus 5 percent.
   2. Air Outlets and Inlets: Plus 10 to minus 10 percent.
   3. Heating-Water Flow Rate: Plus 10 to minus 10 percent.
   4. Cooling-Water Flow Rate: Plus 10 to minus 5 percent.
   5. Hydronic Pumps: Plus 10 to minus 5 percent.

3.25 DRAFT TAB REPORT

A. General: Typewritten, or computer printout, on standard bond paper, in three-ring binder, tabulated and divided into sections by tested and balanced systems.

B. Include a certification sheet in front of binder signed and sealed by the certified testing and balancing supervisor.

C. Include a list of instruments used for procedures, along with proof of calibration.

D. 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. Manufacturer’s installation instructions for smoke and combination fire/smoke dampers, and duct mounted smoke detectors.
   6. Other information relative to equipment performance, but do not include Product Data.

E. General Report Data: In addition to form titles and entries, include the following data in the final report, as applicable:
   1. Title page.
   2. Name and address of TAB firm.
   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 firm who certifies the report.
   10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
   11. Summary of contents including the following:
       a. Indicated versus final performance.

b. Notable characteristics of systems.

12. Nomenclature sheets for each item of equipment.
13. Data for HVAC equipment, including manufacturer, model number, serial number, type, and size.
14. Notes to explain why certain final data in the body of reports varies from indicated values.
15. Test conditions including the following:
    a. Settings for outside-, return-, and exhaust-air dampers.
    b. Conditions of filters.
    c. Face and bypass damper settings at coils.
    d. Sheave and belt sizes for belt-driven equipment.
    e. Settings for supply-air, static-pressure controller.
    f. Other system operating conditions that affect performance.

F. System Diagrams: Include schematic layouts or reduced scale plans of air and hydronic distribution systems. Include the following:

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

G. TAB Data:

1. Results of TAB procedures on standard forms. Indicate “NA” (Not Applicable) in unused fields of standard forms. Do not delete unused fields.

H. System Diagrams: Include reduced-scale plans with mechanical equipment and air outlet designations corresponding to those in the TAB Data.

END OF SECTION

SECTION 23 07 13

DUCT INSULATION

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes insulating the following duct services:
   1. Indoor, concealed supply, return, and outdoor air.
   2. Indoor, exposed supply and return air.
   3. Indoor, concealed, Type I, commercial, kitchen hood exhaust.
   4. Indoor, exposed, Type I, commercial, kitchen hood exhaust.
   5. Outdoor, exposed supply and return.

B. Related Requirements:
   1. Section 23 31 13 "Metal Ducts".

1.2 ACTION SUBMITTALS

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

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
   2. Detail insulation application at elbows, fittings, dampers, specialties, and flanges for each type of insulation.
   3. Detail application of field-applied jackets.
   4. Detail application at linkages of control devices.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality control reports.

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

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

1.5 MOCKUPS

A. Before installing insulation, build mockups if specifically requested in the construction drawings for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by Architect. Use materials indicated for the completed Work.

B. Ductwork Mockups:
   1. One 10-foot section each of rectangular and round straight duct.
   2. One each of a 90-degree mitered round and rectangular elbow, and one each of a 90-degree radius round and rectangular elbow.
   3. One rectangular branch takeoff and one round branch takeoff from a rectangular duct. One round tee fitting.
   4. One rectangular and round transition fitting.
   5. Four support hangers for round and rectangular ductwork.
   6. Each type of damper and specialty.

C. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.

D. Notify Architect seven days in advance of dates and times when mockups will be constructed.

E. Obtain Architect's approval of mockups before starting insulation application.

F. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.

G. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.

1.6 DELIVERY, STORAGE, AND HANDLING

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

1.7 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields.

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

1.8 SCHEDULING

A. Schedule insulation application after pressure testing systems and testing of ductwork.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

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

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

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

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

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

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

1. Products: Subject to compliance with requirements, provide one of the following:
    a. CertainTeed Corp.; Commercial Board.
    b. Johns Manville; Microlite.
    c. Knauf Insulation; Friendly Feel Duct Wrap.
    d. Manson Insulation Inc.; Alley Wrap.
    e. Owens Corning; SOFTR Service Duct Wrap.

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

1. Products: Subject to compliance with requirements, provide one of the following:
    a. CertainTeed Corp.; Commercial Board.
    b. Fibrex Insulations Inc.; FBX.
    c. Johns Manville; 800 Series Spin-Glas.
    d. Knauf Insulation; Insulation Board.
    e. Manson Insulation Inc.; AK Board.
    f. Owens Corning; Fiberglas 700 Series.

H. Fibrous glass liner: Glass fibers bonded with a thermosetting resin. Comply with ASTM C1071.

1. Products: Subject to compliance with requirements, provide one of the following:
    a. CertainTeed Corp.; ToughGard R Liner
    b. Johns Manville; Linacoustic Liner
    c. Knauf Insulation; Performance Liner
    d. Manson Insulation Inc.; Akoustic Liner
    e. Owens Corning; QuietR Liner

2.2 FIRE RATED INSULATION SYSTEMS

A. Fire-Rated Blanket: High-temperature, flexible, blanket insulation with FSK jacket that is tested and certified to provide a 1 or 2 -hour fire rating as appropriate for the installation by an NRTL acceptable to authorities having jurisdiction.

1. Products: Subject to compliance with requirements, provide one of the following:
    a. CertainTeed Corp.; FlameChek.
    b. Johns Manville; Firetemp Wrap.
    c. Nelson Fire Stop Products; Nelson FSB Flameshield Blanket.
    d. Thermal Ceramics; FireMaster Duct Wrap.
    e. 3M; Fire Barrier Wrap Products.
    f. Unifrax Corporation; FyreWrap.

2.3 MASTICS

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

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

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

1. Products: Subject to compliance with requirements available products that may be incorporated into the Work include, but are not limited to, the following:
    a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-80/30-90.
    b. Vimasco Corporation; 749.
2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
5. Color: White.

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

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
    a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-10.

b. Eagle Bridges - Marathon Industries; 550.
c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 46-50.
d. Mon-Eco Industries, Inc.; 55-50.
e. Vimasco Corporation; WC-1/WC-5.

2. Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Solids Content: 60 percent by volume and 66 percent by weight.
5. Color: White.

2.4 SEALANTS

A. FSK and Metal Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
   b. Eagle Bridges - Marathon Industries; 405.
   c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 95-44.
   d. Mon-Eco Industries, Inc.; 44-05.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: Aluminum.
6. For indoor applications, use sealants that have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

B. ASJ Flashing Sealants, and Vinyl and PVC Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: White.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.5 FACTORY APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
   1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
   2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
   3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.
   4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
   5. Vinyl Jacket: White vinyl with a permeance of 1.3 perms when tested according to ASTM E 96/E 96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.6 FIELD APPLIED FABRIC REINFORCING MESH

A. Woven Polyester Fabric: Approximately 1 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in., in a Leno weave, for ducts.
   1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Mast-A-Fab.
      b. Vimasco Corporation; Elastafab 894.

2.7 FIELD APPLIED JACKETS

A. Aluminum Jacket: Comply with ASTM B 209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.
   1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Metal Jacketing Systems.
      b. ITW Insulation Systems; Aluminum and Stainless Steel Jacketing.
      c. RPR Products, Inc.; Insul-Mate.
      d. <Insert manufacturer's name; product name or designation>.
   2. Sheet and roll stock ready for shop or field sizing.
   3. Finish and thickness are indicated in field-applied jacket schedules.
   4. Moisture Barrier for Indoor Applications: 1-mil- thick, heat-bonded polyethylene and kraft paper

5. Moisture Barrier for Outdoor Applications: 3-mil- thick, heat-bonded polyethylene and kraft paper.

PART 3 - EXECUTION

3.1 EXAMINATION

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

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

3.2 PREPARATION

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

3.3 GENERAL INSTALLATION REQUIREMENTS

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

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

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

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

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

F. Keep insulation materials dry during application and finishing.

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

H. Install insulation with least number of joints practical.

I. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
   1. Install insulation continuously through hangers and around anchor attachments.
   2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to

structure. Taper and seal insulation ends at attachment to structure with vapor-barrier mastic.

3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

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

K. Install insulation with factory-applied jackets as follows:
1. Draw jacket tight and smooth.
2. Cover circumferential joints with 3-inch- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
3. Overlap jacket longitudinal seams at least 1-1/2 inches. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 4 inches o.c.
   a. For below ambient services, apply vapor-barrier mastic over staples.
4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.

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

M. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

N. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches with similar methods to those used for butt joints.

3.4 PENETRATIONS

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

B. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches.
1. Comply with requirements in Section 07 84 13 "Penetration Firestopping" for firestopping and fire-resistive joint sealers.

C. 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. Comply with requirements in Section 07 84 13 "Penetration Firestopping."

3.5 INSTALLATION OF MINERAL FIBER INSULATION

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

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.

3.6 FIELD APPLIED JACKET INSTALLATION

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

3.7 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 07 84 13 "Penetration Firestopping."

3.8 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:
   1. Inspect ductwork, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to three location(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.

C. Insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.9 ITEMS NOT INSULATED

A. The following items are not insulated unless specifically stated in the construction documents.
   1. Fibrous-glass ducts.
   2. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
   3. Factory-insulated flexible ducts.
   4. Factory-insulated plenums and casings.
   5. Flexible connectors.
   6. Vibration-control devices.
   7. Factory-insulated access panels and doors.
   8. Return Air Ducts and Plenums in conditioned locations.

3.10 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Supply and Outdoor Air Ducts and Plenums exposed in normally unoccupied locations or concealed: Wrapped with mineral-fiber blanket, 1 1/2” thick Minimum R-6, 0.75- lb/cu. ft. nominal density, Knauf Friendly Feel Duct Wrap or approved equal.

B. Return-Air Ducts and Plenums in unconditioned locations: Wrapped with mineral-fiber blanket, 1 1/2” thick Minimum R-6, 0.75- lb/cu. ft. nominal density, Knauf Friendly Feel Duct Wrap or approved equal.

C. Supply and Outdoor Air Ducts and Plenums exposed in normally occupied spaces: Provide double-wall construction in accordance with Section 233133 Metal Ducts.

3.11 OUTDOOR DUCTS AND PLENUMS INSULATION SCHEDULE

A. Ductwork exposed to outdoor weather conditions shall be double wall construction in accordance with Section 233133 Metal Ducts.

3.12 INDOOR FIELD APPLIED JACKET SCHEDULE

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

B. Ducts and Plenums, Concealed:
   1. ≤ 8’ AFF: Aluminum, Smooth or Corrugated: 0.016 inch thick.
   2. > 8’ AFF: None

END OF SECTION

SECTION 23 07 19

HVAC PIPING INSULATION

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes insulating the following HVAC piping systems:
   1. Chilled-water piping.
   2. Refrigerant suction and hot-gas piping.

B. Related Sections:
   1. Section 23 07 13 "Duct Insulation."
   2. Section 23 21 14 “Preinsulated Piping”

1.2 ACTION SUBMITTALS

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

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
   2. Detail attachment and covering of heat tracing inside insulation.
   3. Detail insulation application at pipe expansion joints for each type of insulation.
   4. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
   5. Detail removable insulation at piping specialties.
   6. Detail application of field-applied jackets.
   7. Detail application at linkages of control devices.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality-control reports.

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

1.5 DELIVERY, STORAGE, AND HANDLING

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

B. Insulation shall be stored so as not to be exposed to moisture, dust, construction debris, etc.

1.6 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.

1.7 SCHEDULING

A. Schedule insulation application after pressure testing systems and owner inspection and approval.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

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

B. 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.

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

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

E. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials.
   1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:

a. Aeroflex USA, Inc.; Aerocel.
b. Armacell LLC; AP Armaflex.
c. K-Flex USA; Insul-Lock, Insul-Tube, and K-FLEX LS.

F. Rigid Phenolic Insulation: Two piece molded rigid phenolic insulation, minimum 5 lbs. per square foot density with factory applied mylar vapor barrier jacket. K-factor maximum 0.21 Btu/in./sq. ft./deg. F. /hr.

1. Trymer Supercel
2. DyTherm Phenolic – Dyplast Products
3. Resolco International - Insul-Phen

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

1. Products: Subject to compliance with requirements, provide the following:
   a. Pittsburgh Corning Corporation; Foamglas.
2. Block Insulation: ASTM C 552, Type I.
3. Special-Shaped Insulation: ASTM C 552, Type III.
4. Board Insulation: ASTM C 552, Type IV.
5. Preformed Pipe Insulation without Jacket: Comply with ASTM C 552, Type II, Class 1.
6. Preformed Pipe Insulation with Factory-Applied ASJ-SSL: Comply with ASTM C 552, Type II, Class 2.
7. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.

H. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 1290, Type I.

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. CertainTeed Corp.; SoftTouch Duct Wrap.
   b. Johns Manville; Microlite.
   c. Knauf Insulation; Friendly Feel Duct Wrap.
   d. Manson Insulation Inc.; Alley Wrap.
   e. Owens Corning; SOFTR All-Service Duct Wrap.

I. Mineral-Fiber, Preformed Pipe Insulation:

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. Fibrex Insulations Inc.; Coreplus 1200.
   b. Johns Manville; Micro-Lok.
   c. Knauf Insulation; 1000-Degree Pipe Insulation.
   d. Manson Insulation Inc.; Alley-K.
   e. Owens Corning; Fiberglas Pipe Insulation.
2. Type I, 850 deg F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ-SSL. Factory- applied jacket requirements are specified in "Factory-Applied Jackets" Article.

J. Mineral-Fiber, Pipe Insulation Wicking System: Preformed pipe insulation complying with ASTM C 547, Type I, Grade A, with absorbent cloth factory-applied to the entire inside surface of preformed pipe insulation and extended through the longitudinal joint to outside surface of insulation under insulation jacket. Factory apply a white, polymer, vapor-retarder jacket with self-sealing adhesive tape seam and evaporation holes running continuously along the longitudinal seam, exposing the absorbent cloth. (REQUIRED IN DATA ROOMS, MDF ROOMS and UPS Room)

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
    a. Knauf Insulation; Permawick Pipe Insulation.
    b. Owens Corning; VaporWick Pipe Insulation.

2.2 INSULATING CEMENTS

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

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
    a. Ramco Insulation, Inc.; Ramcote 1200 and Quik-Cote.

2.3 ADHESIVES

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

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

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
    a. Aeroflex USA, Inc.; Aeroseal.
    b. Armacell LLC; Armaflex 520 Adhesive.
    c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-75.
    d. K-Flex USA; R-373 Contact Adhesive.
2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

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

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
    a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-127.
    b. Eagle Bridges - Marathon Industries; 225.

c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-60/85-70.
d. Mon-Eco Industries, Inc.; 22-25.

2. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

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

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-82.
b. Eagle Bridges - Marathon Industries; 225.
c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-50.
d. Mon-Eco Industries, Inc.; 22-25.

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

E. PVC Jacket Adhesive: Compatible with PVC jacket.

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
a. Dow Corning Corporation; 739, Dow Silicone.
b. Johns Manville; Zeston Perma-Weld, CEEL-TITE Solvent Welding Adhesive.
c. P.I.C. Plastics, Inc.; Welding Adhesive.
d. Speedline Corporation; Polyco VP Adhesive.

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

2.4 MASTICS

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

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

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

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-80/30-90.
b. Vimasco Corporation; 749.

2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.

3. Service Temperature Range: Minus 20 to plus 180 deg F.

4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.

5. Color: White.

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

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-10.
   b. Eagle Bridges - Marathon Industries; 550.
   c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 46-50.
   d. Mon-Eco Industries, Inc.; 55-50.
   e. Vimasco Corporation; WC-1/WC-5.
2. Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Solids Content: 60 percent by volume and 66 percent by weight.
5. Color: White.

2.5 SEALANTS

A. Joint Sealants:

1. Joint Sealants for Cellular-Glass Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
   b. Eagle Bridges - Marathon Industries; 405.
   c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-45.
   d. Mon-Eco Industries, Inc.; 44-05.
   e. Pittsburgh Corning Corporation; Pittseal 444.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Permanently flexible, elastomeric sealant.
4. Service Temperature Range: Minus 100 to plus 300 deg F.
5. Color: White or gray.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

B. FSK and Metal Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
   b. Eagle Bridges - Marathon Industries; 405.
   c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 95-44.

d. Mon-Eco Industries, Inc.; 44-05.

2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: Aluminum.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

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

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: White.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.6 FIELD APPLIED FABIRC REINFORCING MESH

A. Woven Polyester Fabric: Approximately 1 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in., in a Leno weave, for pipe.

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Mast-A-Fab.
   b. Vimasco Corporation; Elastafab 894.

2.7 FACTORY APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.

4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
5. PVDC Jacket for Indoor Applications: 4-mil- thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perm when tested according to ASTM E 96/E 96M and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.
6. Products: Subject to compliance with requirements, provide the following:
    a. Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.

2.8 FIELD APPLIED JACKETS

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

B. FSK Jacket: Aluminum-foil face, fiberglass-reinforced scrim with kraft-paper backing.

C. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D 1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.
1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
    a. Johns Manville; Zeston.
    b. P.I.C. Plastics, Inc.; FG Series.
    c. Proto Corporation; LoSmoke.
    d. Speedline Corporation; SmokeSafe.
2. Adhesive: As recommended by jacket material manufacturer.
3. Color: White, see colors listed in section 230553-2 for Central Plants.
4. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.
    a. Shapes: 45- and 90-degree, short- and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.

D. Aluminum Jacket: Comply with ASTM B 209, Alloy 3003, 3005, 3105, or 5005, Temper H-14.
1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
    a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; Metal Jacketing Systems.
    b. ITW Insulation Systems; Aluminum and Stainless Steel Jacketing.
    c. RPR Products, Inc.; Insul-Mate.
2. Sheet and roll stock ready for shop or field sizing.
3. Finish and thickness are indicated in field-applied jacket schedules.
4. Moisture Barrier for Indoor Applications: 1-mil- thick, heat-bonded polyethylene and kraft paper.
5. Moisture Barrier for Outdoor Applications: 3-mil- thick, heat-bonded polyethylene and kraft paper or 2.5-mil- (0.063-mm-) thick polysurlyn.

6. Factory-Fabricated Fitting Covers:
    a. Same material, finish, and thickness as jacket.
    b. Preformed 2-piece or gore, 45- and 90-degree, short- and long-radius elbows.
    c. Tee covers.
    d. Flange and union covers.
    e. End caps.
    f. Beveled collars.
    g. Valve covers.
    h. Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

E. PVDC Jacket for Indoor Applications: 4-mil- thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perms when tested according to ASTM E 96/E 96M and with a flame- spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.
    1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
        a. Dow Chemical Company (The); Saran 540 Vapor Retarder Film.

F. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.
    1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
        a. Dow Chemical Company (The); Saran 540 Vapor Retarder Film and Saran 560 Vapor Retarder Film.

2.9 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.
    1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
        a. ABI, Ideal Tape Division; 428 AWF ASJ.
        b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
        c. Compac Corporation; 104 and 105.
        d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
    2. Width: 3 inches.
    3. Thickness: 11.5 mils.
    4. Adhesion: 90 ounces force/inch in width.
    5. Elongation: 2 percent.
    6. Tensile Strength: 40 lbf/inch in width.
    7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

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

1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. ABI, Ideal Tape Division; 491 AWF FSK.
   b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827.
   c. Compac Corporation; 110 and 111.
   d. Venture Tape; 1525 CW NT, 1528 CW, and 1528 CW/SQ.
2. Width: 3 inches.
3. Thickness: 6.5 mils.
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.
1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. ABI, Ideal Tape Division; 370 White PVC tape.
   b. Compac Corporation; 130.
   c. Venture Tape; 1506 CW NS.
2. Width: 2 inches.
3. Thickness: 6 mils.
4. Adhesion: 64 ounces force/inch in width.
5. Elongation: 500 percent.
6. Tensile Strength: 18 lbf/inch in width.

D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.
1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. ABI, Ideal Tape Division; 488 AWF.
   b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0800.
   c. Compac Corporation; 120.
   d. Venture Tape; 3520 CW.
2. Width: 2 inches.
3. Thickness: 3.7 mils.
4. Adhesion: 100 ounces force/inch in width.
5. Elongation: 5 percent.
6. Tensile Strength: 34 lbf/inch in width.

E. PVDC Tape for Indoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.
1. Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
   a. Dow Chemical Company (The); Saran 540 Vapor Retarder Tape.
2. Width: 3 inches.

3. Film Thickness: 4 mils.
4. Adhesive Thickness: 1.5 mils.
5. Elongation at Break: 145 percent.
6. Tensile Strength: 55 lbf/inch in width.

2.10 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.

D. Phenolic Insulation: All carbon steel piping operating at a service temperature between 32°F and 300°F or in cycling temperature service where the service temperature is between 32°F and 300°F for more than 20% of the time shall be at a minimum primer coated with an epoxy coating per manufacturer’s installation instructions.

2.11 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 approved by Owner and 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- (75-mm-) wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches (100 mm) o.c.
   3. Overlap jacket longitudinal seams at least 1-1/2 inches (38 mm). Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 4 inches (100 mm) 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.

2.12 PENETRATION

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 07 84 13 "Penetration Firestopping" 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 07 84 13 "Penetration Firestopping."

2.13 GENERAL PIPE INSULATION INSTALLATION

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

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

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

2.14 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.

2.15 INSTALLATION OF MINERAL FIBER PERFORMED PIPE 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.

2.16 FIELD-APPLIED JACKET INSTALLATION

A. 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.

B. 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.

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

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

1. Apply three separate wraps of filament tape per insulation section to secure pipe insulation to pipe prior to installation of PVDC jacket.
2. Wrap factory-presized jackets around individual pipe insulation sections with one end overlapping the previously installed sheet. Install presized jacket with an approximate overlap at butt joint of 2 inches over the previous section. Adhere lap seal using adhesive or SSL, and then apply 1-1/4 circumferences of appropriate PVDC tape around overlapped butt joint.
3. Continuous jacket can be spiral-wrapped around a length of pipe insulation. Apply adhesive or PVDC tape at overlapped spiral edge. When electing to use adhesives, refer to manufacturer's written instructions for application of adhesives along this spiral edge to maintain a permanent bond.
4. Jacket can be wrapped in cigarette fashion along length of roll for insulation systems with an outer circumference of 33-1/2 inches or less. The 33-1/2-inch-circumference limit allows for 2-inch- overlap seal. Using the length of roll allows for longer sections of jacket to be installed at one time. Use adhesive on the lap seal. Visually inspect lap seal for "fishmouthing," and use PVDC tape along lap seal to secure joint.
5. Repair holes or tears in PVDC jacket by placing PVDC tape over the hole or tear and wrapping a minimum of 1-1/4 circumferences to avoid damage to tape edges.

2.17 FINISHES

A. Pipe Insulation with ASJ or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 09 91 13 "Exterior Painting" and Section 09 91 23 "Interior Painting."

1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
   a. Finish Coat Material: Interior, flat, latex-emulsion size.

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

C. Color: See colors listed in Section 23 05 53 “Identification of HVAC Piping and Equipment” and/or color as specified on drawings or specifications selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.

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

2.18 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:
   1. Inspect pipe, fittings, strainers, and valves, randomly selected by Engineer or Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to three locations of straight pipe, three locations of threaded fittings, three locations of welded fittings, two locations of threaded strainers, two locations of welded strainers, three locations of threaded valves, and three locations of flanged valves for each pipe service defined in the "Piping Insulation Schedule, General" Article.

C. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

2.19 PIPING INSULATION SCHEDULE GENERAL

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

2.20 INDOOR PIPING INSULATION SCHEDULE

A. Chilled Water above 40 Deg F: Insulation shall be one of the following:
   1. Rigid Phenolic
      a. Pipe sizes 1-1/2 inches and smaller: 1 inch thick.
      b. Pipe sizes larger than 1.5 inches: 1-1/2 inch thick.
   2. Foamglass
      a. Pipe sizes 4 inches and smaller: 1 inch thick.
      b. Pipe sizes larger than 4 inches: 1-1/2 inch thick.
   3. Flexible Elastomeric
      a. Pipe sizes 1 inch and smaller: 1 inch thick.
      b. Pipe sizes larger than 1 inch: Do not use.

B. Refrigerant Suction and Hot-Gas Piping/Tubing: Flexible elastomeric, preformed pipe insulation.
   1. Pipe sizes 1-1/2 inches and smaller: 1 inch thick.
   2. Pipe sizes larger than 1.5 inches: 1-1/2 inch thick

C. Condensate Drain Piping. Flexible elastomeric preformed piping insulation.
   1. Pipe sizes 1-1/2 inches and smaller: 1 inch thick.
   2. Pipe sizes larger than 1.5 inches: 1-1/2 inch thick

2.21 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

A. Chilled Water: Insulation shall be one of the following:
   1. Rigid Phenolic
      a. Pipe sizes 1-1/2 inches and smaller: 1 inch thick.
      b. Pipe sizes larger than 1.5 inches: 1-1/2 inch thick
   2. Foamglas
      a. Pipe sizes 4 inches and smaller: 1 inch thick.
      b. Pipe sizes larger than 4 inches: 1-1/2 inch thick.
   3. Flexible Elastomeric:
      a. Pipe sizes 1 inch and smaller: 1-1/2 inch thick.
      b. Pipe sizes larger than 1 inch: Do not use.

B. MDF Room and UPS Room:
   1. Mineral-Fiber, Preformed Pipe Insulation with Mineral-Fiber, Pipe Insulation Wicking System:
      a. Pipe sizes 10 inches and smaller: 2 inch thick.

C. Refrigerant Suction and Hot-Gas Piping/Tubing: Insulation shall be one of the following:
   1. Flexible Elastomeric:
      a. Pipe sizes 1 inch and smaller: 1 inch thick.
      b. Pipe sizes larger than 1 inch: 1-1/2 inch thick.

2.22 OUTDOOR, UNDERGROUND PIPING INSULATION SCHEDULE

A. See Section 23 21 14 “Preinsulated Piping” for underground preinsulated chilled water piping.

2.23 INDOOR FIELD APPLIED JACKET SCHEDULE

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

B. Piping, Concealed:
   1. PVC: 20 mils thick.

C. Piping, Exposed:
   1. PVC: 20 mils thick.

2.24 OUTDOOR FIELD APPLIED JACKET SCHEDULE

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

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

C. Piping, Concealed:
   1. Aluminum, stucco embossed: 0.020 inch

D. Piping, Exposed:
   1. Aluminum, stucco embossed: 0.040 inch

2.25 UNDERGROUND FIELD INSTALLED INSULATION JACKET

A. For underground direct-buried piping applications, install underground direct-buried jacket over insulation material.

PART 3 - EXECUTION

3.1 MOCKUP

A. The insulation contactor shall insulation one segment of pipe at one air handling unit containing one pete’s plug, one manual valve, one control valve, one balancing valve, one elbow for inspection by EOR and owner prior to progressing with project. Piping insulation should be covered with jacketing per above.
   1. Valve extensions: Extensions should extend beyond insulation. A complete vapor barrier shall be provided.
   2. Orientation of strainer: Strainer should be positioned to allow full accessibility without any major modifications to insulation.
   3. Valves, PETE’s plug and other penetrations: A complete vapor seal should be provided.
   4. Drain line insulation: All chilled water drain lines should be insulated per specs.
   5. Labeling and identification: Mark flow direction on all piping and label valve and tags
   6. Zeston fittings for valves and fittings: All valves and fittings must have pre-molded zeston fittings. All piping shall be insulated with pre-molded rigid insulation.
   7. Hose end caps: Must be provided on all hoses.
   8. Support and hanger adjustment: All hangers and supports shall fully support weight of pipe. No equipment shall be used to support any weight of piping.

B. Mockup to be reviewed and approved in writing by Architect, Engineer and Owner’s Facilities personnel prior to commencing with insulation throughout the rest of the project.

3.2 PREPARATION

A. Do not install covering before piping and equipment has been tested and approved.

B. Ensure surface is clean and dry prior to installation. Ensure insulation is dry before and during application. Finish with systems at operating conditions.

C. Phenolic Insulation: All carbon steel piping operating at a service temperature between 32°F and 300°F or in cycling temperature service where the service temperature is between 32°F and 300°F for more than 20% of the time shall be at a minimum primer coated with an epoxy coating per manufacturer's installation instructions.

3.3 INSTALLATION

A. Ensure insulation is continuous through inside walls. Pack around pipes with fireproof self-supporting insulation material, fully sealed.

B. Insulate fittings and valves. Maintain access to vents, drain valves, etc.

C. Finish insulation neatly at hangers, supports and other protrusions.

D. Locate insulation or cover seams in least visible locations.

E. Hangers shall be installed on the outside of the insulation to allow for continuous insulation.

F. Provide recovering jackets on exposed insulation throughout, including air handling unit equipment rooms, and central plant. Insulation located in crawl spaces, pipe shafts and suspended ceiling spaces is not considered exposed. Use presized paper under recovering at uneven insulated surfaces.

G. Cold Piping: Cover fittings and valves with pre molded insulation material with vapor barrier. Seal lap joints with 100% coverage of vapor barrier sealant and adhesive. Seal butt joints with 4 inch wide strips of vapor barrier sealed with vapor barrier adhesive. For exposed fittings and valves apply hydraulic setting cement paste over insulation material before applying recovering.

H. Hot Piping: Cover fittings and valves with equivalent thickness of insulation material. Apply with edges tightly butted. Seal joints with vapor barrier tape or sealer.

I. Finish cold surface insulation joints with 4 inch wide strips of vapor barrier sealed with vapor barrier adhesive. Finish insulation with heavy coat of vapor barrier mastic applied over whole body. Finish with a final coat of cement containing 25% by weight of portland cement. Recover and provide an extra coat of lagging adhesive.

J. Repair separation of joints or cracking of insulation due to thermal movement or poor workmanship.

END OF SECTION

SECTION 23 08 00

COMMISSIONING OF HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. The purpose of this section is to specify responsibilities in the Commissioning process, related to IECC and ASHRAE 90.1 compliance as well as for LEED certification.

B. Commissioning Agent shall be 3rd party contracted by the owner directly.

C. Commissioning requires the participation of the Contractor and all Division 23 and Division 25 subcontractors to ensure that all systems are operating in a manner consistent with the Contract Documents. All parties shall be familiar with the commissioning plan which is prepared by the Commissioning Authority (CxA) and shall execute all commissioning responsibilities.

D. Commissioning shall include all new and existing equipment and systems serving the building.

E. Building Controls: Controls Contractor, Mechanical Contractor, and BAS Network Integrator shall provide point to point commissioning and functional performance testing documentation to the Commissioning Agent prior to commencing building commissioning. In addition, Controls Contractor, Mechanical Contractor, and BAS Network Integrator shall provide controls commissioning documentation to the Commissioning Agent sufficient for the Commissioning Agent to prepare the Commissioning Plan. Controls Contractor, Mechanical Contractor, and BAS Network Integrator shall provide support for the Commissioning Agent and shall participate in commissioning activities as required to ensure that all BAS systems are operating properly.

1.2 DEFINITIONS

A. BAS: Building automation system.

B. Contractor: General Contractor, Prime Contractor, and Subcontractors

C. Cx: Commissioning, as defined in Section 01 91 13 "General Commissioning Requirements."

D. CxA: Commissioning Authority

E. DDC: Direct digital controls.

F. HVAC: Heating, ventilating, and air conditioning.

G. "Systems," "Assemblies," "Subsystems," "Equipment," and "Components": Where these terms are used together or separately, they shall mean "as-built" systems, assemblies, subsystems, equipment, and components.

H. TAB: Testing, adjusting, and balancing.

1.3 INFORMATIONAL SUBMITTALS

A. Qualification Data: For BAS and HVAC Testing Technicians.

B. Construction Checklists: Draft construction checklists will be created by Contractors for CxA review.

C. Construction Checklists: Material, installation, and performance test checklists for systems, assemblies, subsystems, equipment, and components to be part of the Cx process.

1. Instrumentation and control for HVAC, including the following:
   a. Control systems equipment.
   b. Control valves.
   c. Control dampers.
   d. Energy meters.
   e. Flow instruments.
   f. Level instruments.
   g. Leak-detection instruments.
   h. Moisture instruments.
   i. Motion instruments.
   j. Position instruments.
   k. Pressure instruments.
   l. Speed instruments.
   m. Temperature instruments.
   n. Vibration instruments.
   o. Weather stations.
   p. Sequence of operations.
2. Hydronic piping, including the following:
   a. Chilled-water, and condenser-water piping, fittings, and specialties.
   b. Hydronic pumps and motors.
   c. Sleeves and sleeve seals.
   d. Meters and gages.
   e. General-duty and specialty valves.
   f. Hangers and supports.
   g. Heat tracing.
   h. Vibration isolation.
3. Refrigerant piping, including the following:
   a. Refrigerant piping, fittings, and specialties.
   b. Refrigerant charge.
   c. Sleeves and sleeve seals.
   d. Meters and gages.
   e. General-duty and specialty valves.
   f. Hangers and supports.

g. Vibration isolation

4. Air distribution systems, including the following:
    a. Supply, return, and exhaust systems.
    b. Metal ducts, liners, and fittings.
    c. Nonmetal ducts and fittings.
    d. Hangers and supports.
    e. Vibration isolation.
    f. Flexible ducts and fittings.
    g. Air-duct accessories, including volume dampers, fire and smoke dampers, turning vanes, sound attenuators, and flexible connectors.
    h. Duct-mounted access doors and panels.
5. Air-handling equipment, including the following:
    a. Fans and motors.
    b. Indoor air-handling units with and without coils, dampers, and filters.
    c. Outdoor air-handling units with and without coils, dampers, and filters.
    d. Motors.
    e. Hangers and supports.
    f. Vibration isolation.
6. Air-filtration equipment, including mounting and support and for the following:
    a. Particulate air filters.
    b. Gas-phase air filters.
    c. Electronic air cleaners.
7. Computer-room air conditioners.
8. Chillers, including the following:
    a. Supports and restraints.
    b. Trim, accessories, and factory-installed controls.
    c. Motors.
9. Cooling towers, including the following:
    a. Supports and restraints.
    b. Trim, accessories, and factory-installed controls.
    c. Sump pumps, motors, controls, and accessories.
    d. Fans, motors, controls, and accessories.
10. Mechanical insulation, including the following:
    a. Duct and plenum insulation.
    b. Fire-suppression, plumbing, and HVAC equipment insulation.
    c. Plumbing and HVAC piping insulation.

D. Test equipment and instrumentation list, identifying the following:
1. Equipment/instrument identification number.
2. Planned Cx application or use.
3. Manufacturer, make, model, and serial number.
4. Calibration history, including certificates from agencies that calibrate the equipment and instrumentation.
5. Equipment manufacturers' proprietary instrumentation and tools. For each instrument or tool, identify the following:
    a. Instrument or tool identification number.

b. Equipment schedule designation of equipment for which the instrument or tool is required.
c. Manufacturer, make, model, and serial number.
d. Calibration history, including certificates from agencies that calibrate the instrument or tool, where appropriate.

1.4 QUALITY ASSURANCE

A. BAS Testing Technician Qualifications: Technicians to perform BAS construction checklist verification tests, construction checklist verification test demonstrations, Cx tests, and Cx test demonstrations shall have the following minimum qualifications:
1. Journey level or equivalent skill level with knowledge of BAS, HVAC, electrical concepts, and building operations.
2. Minimum three years' experience installing, servicing, and operating systems manufactured by approved manufacturer.

B. HVAC Testing Technician Qualifications: Technicians to perform HVAC construction checklist verification tests, construction checklist verification test demonstrations, Cx tests, and Cx test demonstrations shall have the following minimum qualifications:
1. Journey level or equivalent skill level. Vocational school four-year-program graduate or an Associate's degree in mechanical systems, air conditioning, or similar field. Degree may be offset by three years' experience in servicing mechanical systems in the HVAC industry. Generally, required knowledge includes HVAC systems, electrical concepts, building operations, and application and use of tools and instrumentation to measure performance of HVAC equipment, assemblies, and systems.
2. Minimum three years' experience installing, servicing, and operating systems manufactured by approved manufacturer.

C. Testing Equipment and Instrumentation Quality and Calibration:
1. Capable of testing and measuring performance within the specified acceptance criteria.
2. Be calibrated at manufacturer's recommended intervals with current calibration tags permanently affixed to the instrument being used.
3. Be maintained in good repair and operating condition throughout duration of use on Project.
4. Be recalibrated/repaired if dropped or damaged in any way since last calibrated.

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

c. HVAC proprietary test instrumentation and tools become property of Owner at the time of Substantial Completion.

1.5 RESPONSIBILITIES

A. General, Mechanical, Controls/BAS network integrator, and Test and Balance (TAB) Contractors. The commissioning responsibilities applicable to each of the mechanical, controls/BAS network integrator, and TAB contractors of Division 23 are as follows (all references apply to commissioned equipment only):

1. Include and itemize the cost of commissioning in the contract price. Each contractor should include a minimum of an additional 40 person hours for performing commissioning activities, which shall include commissioning documentation, system performance verification, LEED documentation, O&M data, and training.
2. Attend a commissioning scoping meeting and other meetings necessary to facilitate the Commissioning process.
3. Contractors shall provide the CxA with normal cut sheets and shop drawing submittals of commissioned equipment.
4. Provide additional requested documentation for development of Pre-Functional, Functional, and Integrated Testing procedures.
5. Provide measuring instruments and logging devices to record test data and provide data acquisition equipment to record data for the complete range of testing for the required test period.
6. Assist in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
7. Provide assistance to the CxA in preparing the specific functional performance test procedures. Review test procedures to ensure feasibility, safety and equipment protection and provide necessary written limits to be used during the tests.
8. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and the prefunctional checklists from the CxA for all commissioned equipment. Submit to CxA for review and approval prior to startup.
9. During the startup and initial checkout process, execute the contractor related portions of the prefunctional checklists for all commissioned equipment.
10. Perform and clearly document all completed startup and system operational checkout procedures for each system and each item of equipment, and complete pre-functional checklists and submit to CxA.
11. Address current A/E punch list items before functional testing. Air and water TAB shall be completed with discrepancies and problems remedied before functional testing of the respective air- and water-related systems.
12. Provide skilled technicians to execute starting of equipment. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem-solving.
13. Correct deficiencies (differences between specified and observed performance) as interpreted by the CxA, and the Engineer, and retest the equipment.

14. In collaboration with the CxA, perform Integrated Functional Testing of all systems and equipment.
15. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
16. During construction, maintain as-built red-line drawings for all drawings and final CAD as-builts for contractor-generated coordination drawings. Update after completion of commissioning (excluding deferred testing).
17. Provide training of the Owner's operating staff using expert qualified personnel, as specified. Provide comprehensive documentation of training, including hard copies, and video DVDs.
18. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

B. Mechanical Contractor. The responsibilities of the HVAC mechanical contractor, during construction and acceptance phases in addition to those listed in (A) are:
   1. Provide startup for all HVAC equipment.
   2. Assist and cooperate with the TAB contractor and CxA by:
      a. Putting all HVAC equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
      b. Including cost of sheaves and belts that may be required by TAB.
      c. Providing test holes in ducts and plenums where directed by TAB to allow air measurements and air balancing. Providing an approved plug.
      d. Providing temperature and pressure taps according to the Construction Documents for TAB and commissioning testing.
   3. Prepare a preliminary schedule for Division 23 pipe and duct system testing, flushing, and cleaning, equipment start-up and TAB start and completion for use by the CxA. Update the schedule as appropriate.
   4. Notify the CxA, depending on protocol, when pipe and duct system testing, flushing, cleaning, startup of each piece of equipment and TAB will occur. Be responsible to notify the CxA, ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction. Be proactive in seeing that commissioning processes are executed and that the CxA has the scheduling information needed to efficiently execute the commissioning process.

C. Controls Contractor/BAS Network Integrator. The commissioning responsibilities of the controls contractor/BAS Network Integrator, during construction and acceptance phases in addition to those listed in (A) are:
   1. Sequences of Operation Submittals. The submittals of control drawings shall include complete detailed sequences of operation for each piece of equipment, regardless of the completeness and clarity of the sequences in the specifications. They shall include:
      a. An overview narrative of the system generally describing its purpose, components, and function.
      b. All interactions and interlocks with other systems.
      c. Detailed delineation of control between any packaged controls and the building automation system, listing what points the FMS monitors only and what FMS points are control points and are adjustable.

d. Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included but will generally require additional narrative).
e. Start-up sequences.
f. Warm-up mode sequences.
g. Normal operating mode sequences.
h. Unoccupied mode sequences.
i. Shutdown sequences.
j. Capacity control sequences and equipment staging.
k. Temperature and pressure control: setbacks, setups, resets, etc.
l. Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, staging, optimization, demand limiting, etc.
m. Effects of power or equipment failure with all standby component functions.
n. Sequences for all alarms and emergency shutdowns.
o. Seasonal operational differences and recommendations.
p. Initial and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment.
q. Schedules, if known.
r. To facilitate referencing in testing procedures, all sequences shall be written in small statements, each with a number for reference. For a given system, numbers will not repeat for different sequence sections, unless the sections are numbered.

2. Control Drawings Submittal (coordinate with Section 23 09 23)
3. An updated as-built version of the control drawings and sequences of operation shall be included in the final controls O&M manual submittal.
4. Assist and cooperate with the TAB contractor in the following manner:
   a. Meet with the TAB contractor prior to beginning TAB and review the TAB plan to determine the capabilities of the control system toward completing TAB. Provide the TAB any needed unique instruments for setting terminal unit boxes and instruct TAB in their use (handheld control system interface for use around the building during TAB, etc.).
   b. For a given area, have all required prefunctional checklists, calibrations, startup and selected functional tests of the system completed and approved by the CxA prior to TAB.
   c. Provide a qualified technician to operate the controls to assist the TAB contractor in performing TAB or provide sufficient training for TAB to operate the system without assistance.
5. Assist and cooperate with the CxA in the following manner:
   a. Using a skilled technician who is familiar with this building's systems, and provide assistance to CxA as needed, in executing functional testing of the controls system.
6. The controls contractor/BAS network integrator shall prepare a written plan indicating in a step-by-step manner, the procedures that will be followed to test, checkout and adjust the control system prior to functional performance testing. At minimum, the plan shall include for each type of equipment controlled by the automatic controls:

a. System name.
b. List of devices.
c. Step-by-step procedures for testing each controller after installation, including:
    1) Process of verifying proper hardware and wiring installation.
    2) Process of downloading programs to local controllers and verifying that they are addressed correctly.
    3) Process of performing operational checks of each controlled component.
    4) Plan and process for calibrating valve and damper actuators and all sensors.
    5) A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.
d. A copy of the log and field checkout sheets that will document the process. This log must include a place for initial and final read values during calibration of each point and clearly indicate when a sensor or controller has "passed" and is operating within the contract parameters.
e. A description of the instrumentation required for testing.
f. Indicate what tests on what systems should be completed prior to TAB using the control system for TAB work. Coordinate with the CxA and TAB contractor for this determination.
g. As a prerequisite for Functional Testing, provide a signed and dated certification to the CxA, upon completion of the checkout of each controlled device, equipment, and system, that all system programming is complete and in compliance with the Contract Documents.
NOTE: Refer to specific requirements in Section 23 09 23.

D. TAB Contractor - The duties of the TAB contractor, in addition to those listed in (A) are:
1. Submit the outline of the TAB plan and approach for each system and component to the CxA, and the controls contractor six weeks prior to starting the TAB. This plan will be developed after the TAB has some familiarity with the control system.
2. The submitted plan will include:
    a. Certification that the TAB contractor has reviewed the construction documents and the systems with the design engineers and contractors to sufficiently understand the design intent for each system.
    b. An explanation of the intended use of the building control system. The controls contractor will comment on feasibility of the plan.
    c. All field checkout sheets and logs to be used that list each piece of equipment to be tested, adjusted, and balanced with the data cells to be gathered for each.
    d. Detailed step-by-step procedures for TAB work for each system and issue: terminal flow calibration (for each terminal type), diffuser proportioning, branch / submain proportioning, total flow calculations, rechecking, diversity issues, expected problems and solutions, etc.
    e. List of all air flow, water flow, sound level, system capacity and efficiency measurements to be performed and a description of specific test procedures, parameters, formulas to be used.
    f. Details of how total flow will be determined (Air: sum of terminal flows via BAS calibrated readings or via hood readings of all terminals, supply (SA)

and return air (RA) pitot traverse, SA or RA flow stations. Water: pump curves, circuit setter, flow station, ultrasonic, etc.).

g. The identification and types of measurement instruments to be used and their most recent calibration date.
h. Specific procedures that will ensure that both air and water side are operating at the lowest possible pressures and provide methods to verify this.
i. Confirmation that TAB understands the outside air ventilation criteria under all conditions.
j. Details of whether and how minimum outside air cfm will be verified and set, and for what level (total building, zone, etc.).
k. Details of how building static and exhaust fan / relief damper capacity will be checked.

1.6 COMMISSIONING DOCUMENTATION

A. Provide the following information to the CxA for inclusion in the commissioning plan:
1. Plan for delivery and review of submittals, systems manuals, and other documents and reports.
2. Identification of installed systems, assemblies, equipment, and components including design changes that occurred during the construction phase.
3. Process and schedule for completing construction checklists and manufacturer’s prestart and startup checklists for HVAC&R systems, assemblies, equipment, and components to be verified and tested.
4. Certificate of completion certifying that installation, prestart checks, and startup procedures have been completed.
5. Certificate of readiness certifying that HVAC&R systems, subsystems, equipment, and associated controls are ready for testing.
6. Test and inspection reports and certificates.
7. Corrective action documents.
8. Verification of testing, adjusting and balancing reports.

PART 2 - (NOT USED)

PART 3 - EXECUTION

3.1 CONSTRUCTION CHECKLISTS

A. Prepare detailed construction checklists for following HVAC systems, assemblies, subsystems, equipment, and components:
1. Cooling generation systems, including the following:
   a. Water chillers.
   b. Cooling towers.
   c. Direct-expansion refrigeration systems.
2. Central-station air-handling systems.

3. Air and hydronic distribution systems, including the following:
    a. Supply, return, outdoor-air, and exhaust-air distribution systems.
    b. Air terminal units
    c. Hydronic systems.
4. Heating and cooling terminal and unitary equipment, including the following:
    a. Unit heaters.
    b. Fan-coil units.
    c. Electric heating.
    d. Unitary heating and cooling equipment.
5. Controls and instrumentation.
6. TAB verification.

3.2 CONSTRUCTION CHECKLIST REVIEW

A. Review and provide written comments on draft construction checklists. CxA will create required draft construction checklists and provide them to Contractor.

B. Return draft construction checklist review comments within 10 days of receipt.

C. When review comments have been resolved, the CxA will provide final construction checklists, marked "Approved for Use, (date)."

D. Use only construction checklists, marked "Approved for Use, (date)."

3.3 TESTING PREPARATION

A. Certify that all commissioning systems, subsystems, and equipment have been installed, calibrated, and started and are operating according to the Contract Documents.

B. Certify that all instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents, and that pretest set points have been recorded.

C. Certify that testing, adjusting, and balancing procedures have been completed and that testing, adjusting, and balancing reports have been submitted, discrepancies corrected, and corrective work approved.

D. Set systems, subsystems, and equipment into operating mode to be tested (e.g., normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).

E. Inspect and verify the position of each device and interlock identified on checklists.

F. Check safety cutouts, alarms, and interlocks with smoke control and life-safety systems during each mode of operation.

G. Testing Instrumentation: Install measuring instruments and logging devices to record test data as directed by the CxA.

3.4 FUNCTIONAL AND INTEGRATED TESTING REQUIREMENTS

A. Provide technicians, instrumentation, and tools to perform commissioning test at the direction of the CxA.

B. Scope of testing shall include entire installations. Testing shall include measuring capacities and effectiveness of operational and control functions.

C. Test all operating modes, interlocks, control responses, and responses to abnormal or emergency conditions, and verify proper response of building automation system controllers and sensors.

D. Tests will be performed using design conditions whenever possible, and simulated conditions may be used when it is not practical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by the CxA and document simulated conditions and methods of simulation. After tests, return settings to normal operating conditions. The CxA may direct that set points be altered when simulating conditions is not practical.

E. If tests cannot be completed because of a deficiency, document the deficiency, and report it to the Owner. After deficiencies are resolved, reschedule tests.

F. If the testing plan indicates specific seasonal testing, complete appropriate initial performance tests and documentation and schedule seasonal tests.

3.5 CX TEST CONDITIONS

A. Perform tests using design conditions, whenever possible.
   1. Simulated conditions may, with approval of Architect, be imposed using an artificial load when it is impractical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by CxA and document simulated conditions and methods of simulation. After tests, return configurations and settings to normal operating conditions.
   2. Cx test procedures may direct that set points be altered when simulating conditions is impractical.
   3. Cx test procedures may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are impractical.

B. If tests cannot be completed because of a deficiency outside the scope of the HVAC system, document the deficiency and report it to Architect. After deficiencies are resolved, reschedule tests.

C. If seasonal testing is specified, complete appropriate initial performance tests and documentation and schedule seasonal tests.

3.6 TAB VERIFICATION

A. Scope: HVAC air systems and hydronic piping systems.

B. Purpose: Differential flow relationships intended to maintain air pressurization differentials between the various areas of Project.

C. Conditions of the Test:

1. Cx Test Demonstration Sampling Rate: As specified in "Inspections" Article in Section 23 05 93 "Testing, Adjusting, and Balancing for HVAC."
2. Systems operating in full heating mode with minimum outside-air volume.
3. Systems operating in full cooling mode with minimum outside-air volume.
4. For measurements at air-handling units with economizer controls; systems operating in economizer mode with 100 percent outside air.

D. Acceptance Criteria:

1. Under all conditions, rechecked measurements comply with "Inspections" Article in Section 23 05 93 "Testing, Adjusting, and Balancing for HVAC."
2. Additionally, no rechecked measurement shall differ from measurements documented in the final report by more than two times the tolerances allowed.
3. Under all conditions, where the Contract Documents indicate a differential in airflow between supply and exhaust and/or return in a space, the differential relationship shall be maintained.

3.7 OPERATION AND MAINTENANCE (O&M) MANUALS

A. The following O&M manual requirements do not replace O&M manual documentation requirements elsewhere in these specifications.

B. Division 23 and Division 25 contractors shall compile and prepare documentation for all equipment and systems covered in Division 23 and Division 25; and deliver this documentation to the General Contractor (GC) for inclusion in the O&M manuals, according to Division 1, prior to the training of owner personnel.

C. The CxA shall receive a copy of the O&M manuals for review.

D. Special Control System O&M Manual Requirements. In addition to documentation that may be specified elsewhere, the controls contractor shall compile and organize at minimum the following data on the control system with indexed tabs.

1. Copies of the controls training manuals in a separate manual from the O&M manuals.
2. Operation and Maintenance Manuals containing:
   a. Specific instructions on how to perform and apply all functions, features, modes, etc.
   b. Control drawings (refer to Submittal section above for details).
   c. Full as-built sequence of operations for each piece of equipment.

d. Full points list. In addition to the updated points list required in the original submittals (Part 1 of this section), a listing of all rooms shall be provided with the following information for each room:
   1) Floor
   2) Room number
   3) Room name
   4) Air handler unit ID
   5) Reference drawing number
   6) Air terminal unit tag ID
   7) Heating and/or cooling valve tag ID
   8) Minimum cfm
   9) Maximum cfm
e. Full print out of all schedules and set points after testing and acceptance of the system.
f. Full as-built print out of software program.
g. Electronic copy on disk of the entire program for this facility.
h. Marking of all system sensors and thermostats on the as-built floor plan and mechanical drawings with their control system designations.
i. Maintenance instructions, including sensor calibration requirements and methods by sensor type, etc.
j. Control equipment component submittals, parts lists, etc.
k. Warranty requirements.
l. Copies of all checkout tests and calibrations performed by the Contractor (not commissioning tests).

3. The manual shall be organized and subdivided with permanently labeled tabs for each of the following data in the given order:
   a. Sequences of operation
   b. Control drawings
   c. Points lists
   d. Controller / module data
   e. Thermostats and timers
   f. Sensors and DP switches
   g. Valves and valve actuators
   h. Dampers and damper actuators
   i. Program setups (software program printouts)
4. Field checkout sheets and trend logs should be provided to the CxA for inclusion in the Commissioning Record Book.

E. Special TAB Documentation Requirements. The TAB will compile and submit the following with other documentation that may be specified elsewhere in the Specifications.
   1. Final report containing an explanation of the methodology, assumptions, test conditions and the results in a clear format with designations of all uncommon abbreviations and column headings.
   2. The TAB shall mark on the drawings where all traverse and other critical measurements were taken and cross reference the location in the TAB report.

F. Review and Approvals. Review of the commissioning related sections of the O&M manuals shall be made by the CxA.

3.8 TRAINING OF OWNER PERSONNEL

A. The GC shall be responsible for training coordination and scheduling and ultimately to ensure that training is completed. Coordinate with the Owner to obtain input for the training program.

B. Mechanical Contractor. The mechanical contractor shall have the following training responsibilities:

1. Provide the CxA with a training plan two weeks before the planned training.
2. Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece of HVAC equipment.
3. Training shall normally start with classroom sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including startup, shutdown, fire/smoke alarm, power failure, etc.
4. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary, and the demonstration repeated.
5. The appropriate trade or manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer’s representative. Practical building operating expertise as well as in-depth knowledge of all modes of operation of the specific piece of equipment is required. More than one party may be required to execute the training.
6. The controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
7. The training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.
8. Training shall include:
   a. Use of the printed installation, operation and maintenance instruction material included in the O&M manuals.
   b. A review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shut-down, seasonal changeover and any emergency procedures.
   c. Discussion of relevant health and safety issues and concerns.
   d. Discussion of warranties and guarantees.
   e. Common troubleshooting problems and solutions.
   f. Explanatory information included in the O&M manuals and the location of all plans and manuals in the facility.
   g. Discussion of any peculiarities of equipment installation or operation.
   h. The format and training agenda in The HVAC Commissioning Process, ASHRAE Guideline 1-1989R, 1996 is recommended.
   i. Classroom sessions shall include the use of overhead projections, slides, video/audio-taped material as might be appropriate.

9. Hands-on training shall include start-up, operation in all modes possible, including manual, shutdown and any emergency procedures and preventative maintenance for all pieces of equipment.
10. The mechanical contractor shall fully explain and demonstrate the operation, function and overrides of any local packaged controls, not controlled by the central control system.
11. Training shall occur after functional testing is complete, unless approved otherwise by the Project Manager.

C. Controls Contractor/BAS Network Integrator. The controls contractor/BAS network integrator shall have the following training responsibilities:
1. Provide the CxA with a training plan four weeks before the planned training.
2. The controls contractor/BAS network integrator shall provide designated Owner personnel training on the control system in this facility. The intent is to instruct the Owner clearly and completely on all the capabilities of the control system.
3. Training manuals. The standard operating manual for the system and any special training manuals will be provided for each trainee, with three extra copies left for the O&M manuals. In addition, copies of the system technical manual will be demonstrated during training and three copies submitted with the O&M manuals. Manuals shall include detailed description of the subject matter for each session. The manuals will cover all control sequences and have a definitions section that fully describes all relevant words used in the manuals and in all software displays. Manuals will be approved by the CxA. Copies of audiovisuals shall be delivered to the Owner.
4. Training will be tailored to the needs and skill-level of the trainees.
5. The trainers will be knowledgeable on the system and its use in buildings. For the on-site sessions, the most qualified trainer(s) will be used. The Owner shall approve the instructor prior to scheduling the training.
6. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
7. The controls contractor/BAS network integrator shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
8. There shall be three training sessions (Training Plan to be confirmed):
   a. Training I. Control System. The first training shall consist of four (4) hours of actual training. This training may be held on-site or in the supplier's facility. If held off-site, the training may occur prior to final completion of the system installation. Upon completion, each student, using appropriate documentation, should be able to perform elementary operations and describe general hardware architecture and functionality of the system.
   b. Training II. Building Systems. The second session shall be held on-site for a period of eight (8) hours of actual hands-on training after the completion of system commissioning. The session shall include instruction on:
      1) Specific hardware configuration of installed systems in this building and specific instruction for operating the installed system, including HVAC systems, lighting controls and any interface with security and communication systems.

2) Security levels, alarms, system start-up, shut-down, power outage and restart routines, changing setpoints and alarms and other typical changed parameters, overrides, freeze protection, manual operation of equipment, optional control strategies that can be considered, energy savings strategies and set points that if changed will adversely affect energy consumption, energy accounting, procedures for obtaining vendor assistance, etc.
3) All trending and monitoring features (values, change of state, totalization, etc.), including setting up, executing, downloading, viewing both tabular and graphically and printing trends. Trainees will set-up trends in the presence of the trainer.
4) Every screen shall be completely discussed, allowing time for questions.
5) Use of keypad or plug-in laptop computer at the zone level.
6) Use of remote access to the system via phone lines or networks.
7) Setting up and changing an air terminal unit controller.
8) Graphics generation
9) Point database entry and modifications
10) Understanding DDC field panel operating programming (when applicable)

c. Training III. The third training will be conducted on-site six months after occupancy and consist of four (4) hours of training. The session will be structured to address specific topics that trainees need to discuss and to answer questions concerning operation of the system.

D. The TAB contractor shall have the following training responsibilities:
1. TAB shall meet for 3 hours with facility staff after completion of TAB and instruct them on the following:
a. Go over the final TAB report, explaining the layout and meanings of each data type.
b. Discuss any outstanding deficient items in control, ducting or design that may affect the proper delivery of air or water.
c. Identify and discuss any terminal units, duct runs, diffusers, coils, fans, and pumps that are close to or are not meeting their design capacity.
d. Discuss any temporary settings and steps to finalize them for any areas that are not finished.
e. Other salient information that may be useful for facility operations, relative to TAB.

3.9 WRITTEN WORK PRODUCTS

A. Written work products of Contractors will consist of the start-up and initial checkout plan and the filled-out start-up, and Pre-functional Checklists.

END OF SECTION

SECTION 23 09 23

INSTRUMENTATION AND CONTROLS FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. Related Requirements:
1. 23 21 23 Hydronic Pumps
2. 23 36 00 Air Terminal Units
3. 23 64 16 Centrifugal Water Chillers
4. 23 65 00 Cooling Towers
5. 23 73 13 Indoor Central Station Air Handling Units
6. 23 74 13 Outdoor Central Station Air Handling Units
7. 23 81 23 Computer Room Air-Conditioners
8. 25 00 00 Integrated Automation
9. 25 11 00 Integrated Automation Network Devices
10. 25 12 00 Integrated Automation Network Configuration
11. 25 14 00 Integrated Automation Field Devices
12. 25 15 00 Integrated Automation Software
13. 26 05 19 Low Voltage Conductors and Cables
14. 26 05 23 Control Voltage Cables
15. 26 05 33 Raceways and Boxes

B. Coordination with other trades is required wherever architectural features govern the location of Work.

1.2 REFERENCES

A. Rules and regulations of Federal, State, local authorities, and utility companies in force throughout the contract duration.

B. Appendix A, Stability and Accuracy Tables

C. Appendix B, Conductor Requirements Tables

D. Agencies relevant to this section:
1. ANSI-American National Standards Institute
2. ASHRAE-American Society of Heating, Refrigeration, and Air Conditioning Engineers
3. BTL BACnet Testing Laboratories
4. FCC Federal Communications Commission

5. IEC International Electrotechnical Commission
6. ISO International Organization for Standardization
7. NEC National Electrical Code
8. NEMA National Electrical Manufacturers Association
9. OSHA Occupational Safety and Health Administration
10. TIA Telecommunications Industry Association
11. UL Underwriters Laboratories

E. Publications relevant to this Section:
1. ANSI/ASHRAE-Standard 135-2016, A Data Communication Protocol for Building Automation and Control Networks
2. ANSI TIA/EIA-485-A-2012 Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems
3. IEEE 802.3-2018 IEEE Standard for Ethernet
4. IEEE C62.41.1-2002 IEEE Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits
5. IEEE C62.41.2-2002 IEEE Recommended Practice on Characterization of Surges in Low- Voltage (1000 V and Less) AC Power Circuits
6. IEEE C62.41.3-2002 IEEE Guide for Interactions Between Power System Disturbances and Surge Protection Devices
7. ISO 16484-5:201 Building Automation and Control Systems (BACS) -- Part 5: Data communication protocol
8. NEMA 250-2018 Enclosures for Electrical Equipment (1000 Volts Maximum)
9. UL 916-2015 Standard for Energy Management Equipment
10. UL 5085-3-2017 Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers

1.3 ACRONYMS

A. AWG-American Wire Gauge

B. B-AAC-BACnet Advanced Application Controller - Profile with criteria defined by BACnet International.

C. B-ASC-BACnet Application Specific Controller - Profile with criteria defined by BACnet International.

D. B-BC-BACnet Building Controller - Profile with criteria defined by BACnet International.

E. B-SA-BACnet Smart Actuator - Profile with criteria defined by BACnet International.

F. B-SS-BACnet Smart Sensor - Profile with criteria defined by BACnet International

G. BAS-Building Automatic System-The primary software used to read and /or write data to a building system.

H. BBMD-BACnet Broadcast Management Device-capable of forwarding BACnet broadcast messages across subnetworks.

I. BIBB-BACnet-Interoperability Building Blocks- Standardized documentation of a devices BACnet functionality across the network supported by ASHRAE 135.

J. BTL-BACnet Testing Laboratories supports interoperability testing for BACnet device.

K. EMS-Energy Management System

L. COV-Change of Value trending increment that records data every time a value changes a pre specified amount.

M. DDC-Direct Digital Controller containing internal programming logic and input/output capabilities and is typically directly associated with equipment.

N. PID-Proportional Integral Derivative-Control algorithm used to adjust an output based upon the difference between a process variable and setpoint variable.

O. INT-Interval Trending increment that records data on a predefined time interval.

P. IP-Interval Protocol Set of rules governing the format of data sent over the internet or other networks.

Q. GUI-Graphic user interface term for graphical pictation allowing user to read/write data.

R. LAN-Local Area Network a collection of devices interconnected in one physical location.

S. O&M-Operations and Maintenance term to define documentation that illustrates both the operation and maintenance of a product.

T. PICS-Protocol Implementation-Conformance Statement used to describe the BACnet capabilities of a device.

U. SaaS-Subscription as a Service-service or application subscribed for use while on reoccurring payment.

V. SLA-Service Level Agreement a commitment between a service provider and a client.

1.4 DEFINITIONS

A. Algorithm: A process or set of rules to be followed in calculations or other problem-solving operations.

B. BACnet: Building Automation and Control Networks communication protocol developed by ASHRAE.

C. BACnet Object: The concept of organizing BACnet information into standard components with various associated properties.

D. Bridge: A repeater that connects two LANs on same network protocol across different data link layers.

E. Controls Contractors: The sub-contractors installing and configuring the devices.

F. Date of Acceptance: The date determined between owner and the sub-contractor that the equipment is finalized and tested and is turned over to owner.

G. Device: A type of DDC or network component used for monitoring and or/ control.

H. Enterprise: Software used to satisfy the needs of organization.

I. Ethernet: A computer networking architecture consisting of various local area networking protocols and devices.

J. Equipment: Term referencing a controlled component.

K. Fault: BACnet Notification state indicating that loss of communication or sensor.

L. Field Device: A type of DDC component used for direct monitoring and/or control of a piece of equipment or system.

M. Firmware: Permanent software programmed into read only memory and provides low level hardware control.

N. Gateway: Connects two dissimilar protocols by translating the data from one system to another.

O. Integration Contractor: The subcontractors responsible of the devices being installed on the network.

P. Integration Project: A project requiring data passing between installed controls of owner systems including but not limited to the BAS Supervisor.

Q. Integrate: The act of connecting disparate BMS systems to a common platform.

R. Integrator: Integrates one system into another by acting as both a router and a gateway, and is capable of other functions including trending, scheduling, notifications, and other programming features

S. IP Address: A unique string of numbers separated by periods that identifies each computer using the internet protocol to communicate over a network.

T. Loop: Synonymous with PID

U. OFFNORMAL: BACnet Notification state indicating that a parameter is met to indicate an off normal event.

V. Network: Multiple devices communicating with one another.

W. Non-Programmable: A device that has pre-programmed language or logic that cannot be rewritten or only has pre selectable options.

X. Object: Data or packet or data on a network.

Y. Points: Software representation of virtual and physical inputs and outputs.

Z. Programable: A device that does not have pre-programmed language or logic.

AA. Repeater: A device used to replicate signal data to increase transmission distance.

BB. Router: Routes data packets across IP addresses on different LANs/Wans with the ability to allow or deny.

CC. Subnet: Also known as a subnetwork, is a logical subdivision of a network.

DD. System: Term referencing multiple pieces of equipment acting in conjunction.

1.5 SYSTEM DESCRIPTION

A. The control system will consist of a high-speed, peer-to-peer network of DDC controllers and a web-based operator interface.

B. The system will directly control HVAC equipment as specified on the Drawings.

C. Each field device will be capable of stand-alone operation. Furnish energy conservation features such as optimal start and stop, night setback, request-based logic, and demand level adjustment of setpoints as specified in the sequence.

D. I/O points, virtual points, schedule objects, trend objects, alarm objects, and point naming conventions will adhere to requirements specified in Division 25 for algorithms.

E. See Division 25 for system integration and operator interface requirements.

1.6 APPROVED CONTROLLED SYSTEMS

A. Use control system hardware and software that meet the requirements of this specification.

1.7 QUALITY ASSURANCE

A. Controls Sub-Contractor and Manufacturer Qualifications
   1. The Controls Sub-Contractor must have a minimum of five (5) years of demonstrated technical expertise with building automation systems as well as subsystem requiring integration during the project duration. The Controls Sub-Contractor must also have an established working relationship with the Control System Manufacturer.

2. Controls Sub-Contractor will have successfully completed Control System Manufacturer's control system training. Upon request, Controls Sub-Contractor will present record of completed training including course outlines.

B. Project requirements are divided between responsibilities of Controls Sub-Contractor and Integration Sub-Contractor. If Controls Sub-Contractor and Integration Sub-Contractor are the same sub-contractor, approvals will still have to be completed by owner as outlined in this division document.

1.8 CODES AND STANDARDS

A. Work, materials, and equipment will comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation will comply with current editions in effect 30 days prior to receipt of bids of the following codes:
1. National Electric Code (NEC)
2. International Building Code (IBC)
3. International Mechanical Code (IMC)

1.9 SYSTEM PERFORMANCE

A. System will conform to the following minimum standards over network connections. Systems will be tested using manufacturer's recommended hardware and software for operator workstation.
1. Custom and standard applications will be capable of running as often as once every 5 sec. Select execution times consistent with the mechanical process under control.
2. Programmable controllers will be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.
3. System will report values with minimum end-to-end accuracy listed in Appendix A, Table 1.
4. Control loops will maintain measured variable at setpoint within tolerances listed in Appendix A, Table 2.
5. See Division 25 for operator interface requirements.

1.10 SUBMITTAL REQUIREMENTS

A. Submittals pertaining to this section revolve around field devices only. Integrated equipment and operator interface submittals will be provided by the Integration Sub-Contractor. See Division 25 for integrated equipment submittal requirements.

B. Provide shop drawings and other submittals on hardware, software, and equipment to be installed or furnished in PDF file format.

C. Begin no work until submittals have been approved for conformity with design intent.

D. When manufacturer's cutsheets apply to a product series rather than a specific product, clearly indicate applicable data by highlighting or by other means. Clearly reference covered specification and drawing on each submittal. General catalogs will not be accepted as cutsheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal approval does not relieve Controls Sub-Contractor of responsibility to supply quantities to complete work.

1.11 SUBMITTALS

A. The following submittals will be provided as part of the bid package:
   1. See Division 25 Section 25 00 00 “Integrated Automation” for general bid package document requirements.
   2. Hardware Product Data noted in Division 25 Section 25 00 00 “Integrated Automation” will be required for the relevant items listed below:
      a. Direct Digital Controllers
      b. Field Panels and Enclosures
      c. Transducers and Transmitters
      d. Sensors: must include accuracy data
      e. Actuators
      f. Valves
      g. Relays and Switches
      h. Power Supplies
      i. Batteries
      j. Wiring and Raceways

B. The following submittals will be provided as part of the pre-submittal package:
   1. See Division 25 Section 25 00 00 “Integrated Automation” for general pre-submittal document requirements.
   2. Device Object Identification will not be required as part of the pre-submittal package for field devices.

C. The following submittals will be provided as part of the submittal package:
   1. See Division 25 Section 25 00 00 “Integrated Automation” for general submittal document requirements.
   2. In addition to the submittal requirements noted in Division 25 Section 25 00 00 “Integrated Automation” the following will also be required:
      a. Schematic diagram of each controlled system with associated control and monitoring points labeled. Graphically show locations of controlled and monitored elements.
      b. Schematic wiring diagram of each controlled system. Label control elements, monitoring elements, and terminals.
      c. Names used to note controlled and monitored elements must follow the owner standard naming conventions. Names must match between diagrams.
      d. Instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.

e. Complete description of control system operation including sequences of operation. Include and reference schematic diagram of controlled system. List I/O points and software points specified on the Drawings. Indicate alarmed and trended points.

f. For equipment being integrated into systems other than Niagara N4, a graphical representation for each unique system will be required as part of the submittal.

g. For equipment being integrated into Niagara N4, see Division 25 Section 25 00 00 “Integrated Automation” for submittal graphical requirements.

D. The following submittals will be provided as part of the programming stage as device information becomes available before devices can be installed on the owner network:

1. See Division 25 Section 25 00 00 “Integrated Automation” for general programming stage document requirements.

E. The following will be provided as part of the Checkout Forms:

1. Description of process, report formats, and checklists to be used in the Drawings.

F. The following will be provided as part of the final close-out package:

1. Project Record Documents. Submit record (as-built) documents upon completion of installation for approval prior to final completion. Submittal will consist of:

a. As-built versions of submittal product data.

b. Names, addresses, and telephone numbers of installing subcontractors and service representatives for equipment and control systems.

c. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.

d. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.

e. Backup copies of custom programs generated for programmable controllers and must be capable of viewing using furnished programming tools.

f. List of recommended spare parts with part numbers and suppliers.

g. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.

h. Complete original-issue copies of furnished software.

i. Licenses, guarantees, and warranty documents for equipment and systems.

j. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

1.12 OWNER TRAINING

A. Owner training for DDC field equipment will be performed by the Controls Sub-Contractor and will be specific to the control system installed during the project.

B. The Controls Sub-Contractor will provide a course outline and materials at least six weeks before first class. Engineer will modify course outlines and materials, if necessary, to meet General Owner's needs. Engineer will review and approve course outlines and materials at least three weeks before first class.

C. Training will not be scheduled until Control System Demonstration and Acceptance has been completed.

   1. If control system installation and programming coincide with device integration, owner training for device integration may be completed in parallel with training mentioned within this specification.

D. Based upon project size, a minimum of 8 hours of training will provided to owner, organized into two (2) separate sections at four (4) hours a piece, unless otherwise stated by owner.

E. Provide a factory-trained instructor or representative to give full instructions to designated personnel in the operation, maintenance, and programming of each piece of equipment or system. Instructors shall be thoroughly familiar with aspects of the subject matter. The Sub-Contractor will provide equipment and material required for classroom training.

F. Proposed training instructor qualifications will be provided to owner and subject to approval by owner.

G. Training will include classroom instruction and hands-on field instruction.

H. Minimum requirements for classroom instruction are the following:

   1. Review of project record documentation
      a. Each student must be provided a copy of the final project submittals.
   2. Maintenance procedures and schedules
   3. Pertinent safety requirements
   4. Introduction to controller programming and overview of the programming application interface. This will also include:
      a. Uploading, downloading, and backing up programs
      b. Review of setpoint optimization and loop tuning concepts
      c. Configuration of installed devices, modifying system parameters.
      d. Controller training must be completed in the classroom with networked working controllers that are representative of the installed hardware.
   5. Review of installed components and how to install/replace, maintain, commission, and diagnose them
   6. General review of sequence of operation and control logic for the project site.
   7. Training manuals will be provided and include screen captures with detailed instructional annotation for each step required to complete portions of owner training.
   8. Additional topics can be requested by owner in advance of the training sessions. Each additional topic will require the Sub-Contractor to prepare and submit training manuals with the same level of detail as described above.
   9. Training is subject to be recorded by owner for internal use.

I. Minimum requirements for field instruction:
   1. Walkthrough of the project to locate mechanical equipment and associated installed control devices and components.

1.13 OWNERSHIP OF PROPRIETARY MATERIAL

A. Project-specific software and documentation will become owner's property. This includes, but is not limited to:
   1. Record drawings
   2. Database
   3. Application programming code
   4. Documentation

PART 2 - PRODUCTS

2.1 MATERIALS

A. Use new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved in writing by owner. Spare parts will be available for at least five years after completion of this contract.

2.2 COMMUNICATION

A. Communication protocol requirements will comply with Division 25. Where communication protocol requirements of Division 23 differ from Division 25, Division 25 will take precedence but will not supersede additional requirements noted herein.

B. Install new wiring and network devices as required to provide a complete and workable control network. Use existing Ethernet backbone for network segments marked "existing" on project drawings.

C. Each controller will have a communication port for temporary connection to a laptop computer or other operator interface. Connection will support memory downloads and other commissioning and troubleshooting operations.

D. Controllers with real-time clocks will use the BACnet Time Synchronization service. System will automatically synchronize system clocks daily from an operator-designated controller via the internetwork. If applicable, system will automatically adjust for daylight saving and standard time.

E. System will be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

2.3 CONTROLLER SOFTWARE

A. Field controllers must be programmed and configured to function as specified on the Drawings.

B. Controller applications will be editable through a web browser interface or engineering workstation.

C. Application programming software will require a username and password to view, edit, add, or delete data.
   1. The software must automatically log out each operator if no keyboard or mouse activity is detected. Operators will be able to adjust automatic log out delay.
   2. Security data, such as user passwords, must be stored in an encrypted format. System will not display operator passwords.

D. Energy Conservation and Peak Demand Management.
   1. The building management system will monitor building power consumption from building power meter pulse generator signals or from building feeder line watt transducer or current transformer.
   2. When power consumption exceeds adjustable levels, building management system will automatically adjust setpoints, de-energize low-priority equipment, and take other programmatic actions to reduce demand as specified on the Drawings. When demand drops below adjustable levels, building management system will restore loads as specified.
   3. The building management system will stagger controlled equipment start after unoccupied periods or power outages. Operator will be able to adjust equipment restart order and time delay between equipment restarts.

E. Controllers must provide the following:
   1. Direct- and reverse-acting PID (proportional-integral- derivative) algorithms. Each algorithm will have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm will calculate a time-varying analog value that can be used to position an output or to stage a series of outputs.
   2. Ability to accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.
   3. Ability to calculate a sliding-window average (rolling average). Operator will be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.
   4. Ability to prevent equipment short cycling by means of adjustable minimum on-time and off-time settings.
   5. Ability to provide direct- and reverse-acting on and off algorithms with adjustable differential to cycle a binary output based on a controlled variable and setpoint.
   6. Ability to provide an algorithm that can totalize runtime for each binary input and output. Operator will be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as specified on the Drawings.

F. See Division 25 Section 25 14 00 “Integrated Automation” for scheduling and alarming requirements for field devices.

2.4 CONTROLLERS

A. See Division 25 Section 25 14 00 “Integrated Automation" for acceptable controller manufacturers and controller basis of design.

B. Provide BACnet Building Controllers (B-BC), Advanced Application Controllers (B-AAC), Application Specific Controllers (B-ASC), Smart Actuators (B-SA), and Smart Sensors (B-SS) to achieve performance specified in System Performance. Every device which executes control logic and directly controls HVAC equipment must conform to Division 25 requirements for BACnet field devices.

C. B-ASC controllers used in VAV box applications must be provided with integrated damper actuator and air flow sensor.

D. Hardwired actuators and sensors may be used in lieu of BACnet Smart Actuators and Smart Sensors, unless otherwise specified by owner.

E. Each controller must contain a service communication port for local communication to the device.

F. Each controller must contain a real-time clock for accurate equipment scheduling.

G. Equipment specified within the project scope will be controlled by a single controller to provide stand-alone control in the event of communication failure. I/O points specified for a piece of equipment will be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network.

H. Where a single controller is unable to provide an adequate amount of I/O to fulfill algorithm requirements, the controller may utilize one or more I/O modules to provide additional space. The I/O modules must remain on an isolated network with the host controller.

I. Controller hardware will be suitable for anticipated ambient conditions.

J. Controllers used outdoors or in wet ambient conditions will be mounted in waterproof, air conditioned enclosures and will be rated for operation at -29°C to 60°C (-20°F to 140°F).

K. Controllers used in conditioned space will be mounted in dust-protective enclosures and will be rated for operation at 0°C to 50°C (32°F to 120°F).

L. Controllers must have diagnostic LEDs for power, communication, and processor.

M. Each B-BC and B-AAC selected for the project must have an available option for an integrated local interface with password locked display.

   1. The Operator must be able to use the interface to view and edit required data specified by owner.

N. Controllers must have field removable terminal strips.

O. Controller memory must support operating system, database, and programming requirements. At the time of commissioning each controller must demonstrate memory usage and total point count are below the manufacturer’s recommended operating limit.

P. Controllers will retain BIOS and application programming in nonvolatile memory to prevent data loss in the event of a power cycle.

Q. Controllers will be able to operate at 90% to 110% of nominal voltage rating and will perform an orderly shutdown below 80% nominal voltage. Operation will be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft.).

R. Controllers must be provided with field replaceable fuses for overcurrent protection. Overcurrent protection must be a minimum of 125% of total power consumption.

2.5 INPUT AND OUTPUT REFERENCE

A. Each controller must be selected with an additional 20% capacity for each input and output type for expanded capability.

B. Shorting an input or output point to itself, to another point, or to ground will cause no controller damage. Input or output point contact with up to 24 V for duration will cause no controller damage.

C. Binary inputs will provide a wetting current of at least 12 mA and will be protected against contact bounce and noise.

D. Binary inputs will sense dry contact closure without application of power external to the controller.

E. Pulse accumulation inputs will conform to binary input requirements and will accumulate up to 10 pulses per second.

F. Analog inputs must be capable of monitoring a minimum of 0-10 VDC, 4-20 mA, or resistance (thermistor or RTD) signals. Analog inputs will be compatible with and field configurable to commonly available sensing devices.

G. Analog outputs must be capable of modulating a minimum of 0-10 VDC or 4-20 mA signals as required to properly control output devices. Each analog output used in conjunction with major equipment will have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs will not drift more than 0.4% of range annually.

H. Inputs and outputs that can be designated as either binary or analog in software will conform to the provisions of this section that are appropriate for their designated use.

2.6 POWER SUPPLIES AND LINE

A. Control transformers will be UL listed. Furnish Class 2 current-limiting type or furnish over- current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

B. DC power supplies must include the following:
   1. Must match output current and voltage requirements.
   2. Must have built-in over-voltage and over-current protection and will be able to withstand 150% current overload for at least three seconds without trip-out or failure.
   3. Must be full-wave rectifier type with an output ripple of 5.0 mV maximum peak-to-peak.
   4. Regulation will be 1.0% line and load combined, with 100-microsecond response time for 50% load changes.
   5. Must operate between 0°C and 50°C (32°F and 120°F). EM/RF will meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.

C. Line voltage units will be UL recognized and CSA listed.

D. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection will have:
   1. Dielectric strength of 1000 V minimum.
   2. Response time of 10 nanoseconds or less.
   3. Transverse mode noise attenuation of 65 dB or greater.
   4. Common mode noise attenuation of 150 dB or greater at 40-100 Hz.

2.7 AUXILIARY CONTROL DEVICES

A. Control Valves:
   1. Manufacturer: Belimo or approved equal.
   2. Select body and trim materials in accordance with manufacturer's recommendations for design conditions and service shown.
   3. Provide two- or three-way control valves for two-position or modulating service as shown.
   4. Water Valves:
      a. Valves providing two-position service will be quick opening.
      b. Valve actuator and trim will provide the following minimum close-off pressure ratings.
         1) 150% of total system (pump) head for two-way valves.
         2) 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head for three-way valves.
      c. Valves providing modulating service will have equal percentage ports.
      d. Sizing:
         1) Line size for two position service.
         2) Select pressure drop equal to the greatest of twice the pressure drop through heat exchanger (load), 50% of the pressure difference

between supply and return mains, or 35 kPa (5 psi) for two-way modulating service.

3) Select pressure drop equal to the smaller of twice the pressure drop through the coil exchanger (load) or 35 kPa (5 psi) for three-way modulating service.

5. Sizing:
   a. Select pressure drop equal to 10%-20% of inlet psig for two position service.
   b. Select pressure drop equal to 80% of inlet psig for modulating service at 100 kPa (15 psig) or less.
   c. Select pressure drop equal to 50% of inlet psig for modulating service at 101-350 kPa (16-50 psig).
   d. Select pressure drop as scheduled on drawings for modulating service at or over 350 kPa (50 psig).

B. Electric Damper and Valve Actuators.
   1. Manufacturer: Belimo or approved equal.
   2. Must be available with mechanical or electronic stall protection to prevent actuator damage throughout the actuator's rotation.
   3. Actuators used for power-failure and safety applications will have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).
   4. Actuators used for water valve control will be selected in accordance with manufacturer’s recommendations to prevent hydraulic shock.
   5. Proportional actuators will accept a 0-10 Vdc or a 0-20 mA control signal and will have a 2-10 Vdc or 4-20 mA operating range.
   6. 24 Vac and 24 Vdc actuators will operate on Class 2 wiring.
   7. Operators will be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators will have an external manual gear release. Spring- return actuators with more than 7 N·m (60 in.-lb.) torque capacity will have a manual crank.

C. Binary Temperature Devices:
   1. Manufacturer: Honeywell or approved equal.
   2. Low-voltage space thermostats will be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C-30°C (55°F- 85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
   3. Line-voltage space thermostats will be bimetal- actuated, open-contact type or bellows- actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
   4. Low-limit airstream thermostats will be UL listed, vapor pressure type. Element will be at least 6 m (20 ft.) long. Element will sense temperature in each 30 cm (1 ft.) section and will respond to lowest sensed temperature. Low-limit thermostat will be manual reset only.

D. Temperature Sensors:

1. Manufacturer: Honeywell or approved equal.
2. Temperature sensors will be Resistance Temperature Device (RTD) or thermistor.
3. Duct sensors will be single point or averaging as shown on drawings. Averaging sensors will be a minimum of 1.5 m (5 ft.) in length per 1 m2(10 ft2) of duct cross-section.
4. Immersion sensors must be provided with a separable stainless steel well. Well pressure rating will be consistent with system pressure it will be immersed in. Well will withstand pipe design flow velocities.
5. Space sensors will have remote setpoint adjustment, occupancy override, vertical wall box enclosure, B-SA Bus screw terminal block, BACnet listed sensor, and communication port.

E. Humidity Sensors:

1. Manufacturer: Honeywell or approved equal.
2. Duct and room sensors will have a sensing range of 20%-80%.
3. Duct sensors will have a sampling chamber.
4. Outdoor air humidity sensors will have a sensing range of 20%-95% RH and will be suitable for ambient conditions of 40°C-75°C (40°F-170°F).
5. Humidity sensors will not drift more than 1% of full scale annually.

F. Flow Switches:

1. Air Flow:
   a. Manufacturer: Cleveland Controls or approved equal.
   b. Flow-proving switches will be differential pressure type or thermal dispersion type air flow switches.
   c. Differential pressure switches will be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum) and will have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.
2. Water Flow:
   a. Flow proving switches are not permitted for water service use.

G. Flow Sensors:

1. Air Flow:
   a. Manufacturer: Ebtron or approved equal.
   b. Air flow sensors will be solid state thermal dispersion type with steel construction and a flanged face for easy mounting and flow straighteners for circular and rectangular ducts.
   c. Solid state thermal dispersion type sensors will have field selectable and field scalable analog output signals.
      1) Selectable output signals will be at minimum 0-10 VDC and 0-20 mA.
      2) Scalable range up to a minimum of 10% over design flow conditions.

d. Unit accuracy must meet or exceed parameters listed in Appendix A of this document.

e. Air flow sensors and stations will be available with a local display indicating live flow values.

f. Air flow sensors and stations will be UL listed with NIST-traceable calibration certification and a NEMA 1 enclosure unless otherwise specified.

2. Water Flow:

a. Manufacturer: IFM or approved equal.

b. Water flow sensors will be solid state thermal dispersion type with construction material rated for the size and type of piping material.

c. Sensors will have field selectable and field scalable analog output signals.

1) Selectable output signals will be at minimum 0-10 VDC and 0-20 mA.

2) Scalable range up to a minimum of 10% over design flow conditions.

d. Unit accuracy must meet or exceed parameters listed in Appendix A of this document.

e. Water flow sensors will be UL listed with NIST-traceable calibration certification and a NEMA 4 enclosure unless otherwise specified.

H. Relays:

1. Manufacturer: IDEC or approved equal.

2. Control and status relays will be plug-in IDEC type, UL listed, and will have dust cover and LED "energized" indicator with manual override button. Contact rating, configuration, and coil voltage will be suitable for application.

3. Time delay relays will be solid-state plug-in type, UL listed, and will have adjustable time delay. Delay will be adjustable ±100% from setpoint shown. Contact rating, configuration, and coil voltage will be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

I. Current Transmitters:

1. Manufacturer: Veris or approved equal.

2. AC current transmitters will be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 mA two- wire output. Full-scale unit ranges will be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy will be ±1% full-scale at 500 ohm maximum burden.

3. Transmitter will meet or exceed ANSI/ISA S50.1 requirements and will be UL/CSA recognized.

4. Unit will be split-core type for clamp-on installation on existing wiring.

J. Current Transformers:

1. AC current transformers will be UL/CSA recognized and will be completely encased (except for terminals) in approved plastic material.

2. Transformers will be available in various current ratios and will be selected for ±1% accuracy at 5 A full-scale output.

3. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.

K. Voltage Transmitters:
  1. Manufacturer: Omega or approved equal.
  2. AC voltage transmitters will be self-powered single-loop (two-wire) type, 4-20 mA output with zero and span adjustment.
  3. Adjustable full-scale unit ranges will be 100-130 Vac, 200-250 Vac, 250-330 Vac, and 400-600 Vac. Unit accuracy will be ±1% full-scale at 500 ohm maximum burden.
  4. Transmitters will meet or exceed ANSI/ISA S50.1 requirements and will be UL/CSA recognized at 600 Vac rating.

L. Power Monitors:
  1. Power monitors will be three-phase type and will have three-phase disconnect and shorting switch assembly, UL listed voltage transformers, and UL listed split-core current transformers.
  2. Power monitors will be provided with a selectable pulse rate output for kWh reading. Power monitors will operate with 5 A current inputs and maximum error of ±2% at 1.0 power factor or ±2.5% at 0.5 power factor.

M. Current Switches:
  1. Manufacturer: Veris or approved equal.
  2. Current-operated switches will be self-powered, solid-state with adjustable trip current. Select switches to match application current and DDC system output requirements.

N. Pressure Transducers:
  1. Manufacturer: Setra or approved equal.
  2. Transducers will have linear output signal and field-adjustable zero and span and will be available with a local display indicating live flow values.
  3. Continuous operating conditions of positive or negative pressure 50% greater than calibrated span will not damage transducer sensing elements.
  4. Water pressure transducer diaphragm will be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Transducer will have 4-20 mA output, suitable mounting provisions, and block and bleed valves.
  5. Water differential pressure transducer diaphragm will be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Over-range limit (differential pressure) and maximum static pressure will be 2000 kPa (300 psi.) Transducer will have 4-20 mA output, suitable mounting provisions, and 5-valve manifold.

O. Differential Pressure Switches:
  1. Manufacturer: Penn or approved equal.
  2. Differential pressure switches will be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum) and will have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

P. Pressure-Electric (PE) Switches:

1. Manufacturer: Penn or approved equal.
2. PE switches will be UL listed, pilot duty rated (125 VA minimum) or motor control rated, metal or neoprene diaphragm actuated, operating pressure rated for 0-175 kPa (0-25 psig), with calibrated scale minimum setpoint range of 14-125 kPa (2-18 psig).
3. Provide one- or two-stage switch action (SPDT, DPST, or DPDT) as required by application.
4. Switches will be open type (panel-mounted). Exception:
   a. Switches will be enclosed type for remote installation. Enclosed type will be NEMA 1 unless otherwise specified.
5. Each pneumatic signal line to PE switches will have permanent indicating gauge.

Q. Local Control Panels:

1. Manufacturer: Hoffman or approved equal.
2. Indoor control panels will be fully enclosed NEMA 1 construction with hinged door key-lock latch and removable sub-panels. A common key will open each control panel and sub- panel.
3. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals will be UL listed for 600 V service, individually identified per control and interlock drawings, with adequate clearance for field wiring.
4. Each local panel will have a control power source power switch (on-off) with overcurrent protection.
5. Each panel will be sized to accept 20% more controller units than originally installed for expansion.
6. Outdoor control panels will be cooled by a packaged air conditioning unit like the Rittal Thermoelectric Enclosure Cooling Unit or approved equal.

R. Environment:

1. Auxiliary Control Devices will be suitable for anticipated ambient conditions.
2. Devices used outdoors or in wet ambient conditions will be mounted in waterproof enclosures and will be rated for operation at -29°C to 60°C (-20°F to 140°F).
3. Devices used in conditioned space will be mounted in dust-protective enclosures and will be rated for operation at 0°C to 50°C (32°F to 120°F).
4. The Devices themselves will possess the appropriate NEMA Rating for the intended environment. Plastic covers, canvas bags, or other supplemental enclosures are unacceptable.

2.8 WIRING AND RACEWAYS

A. Conductors will conform to tables listed in Appendix B, Conductor Requirements Tables.

B. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.

C. Insulated wire will use copper conductors and will be UL listed for 90°C (200°F) minimum service.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Architect or Engineer for resolution before starting rough-in work.

B. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to Engineer for resolution before starting rough-in work.

C. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies to Engineer and obtain written instructions for changes necessary to accommodate work with work of others. Controls Contractor will perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.2 PROTECTION

A. Controls Contractor will protect against and be liable for damages to performed work and/or damages to material caused by work performed by the Controls Contractor, work performed by the Controls Contractor’s employees, and/or work performed by the Controls Contractor’s Sub Contractor.

B. Controls Contractor will be responsible for work and equipment until inspected, tested, and accepted by owner.

C. Protect material not immediately installed.

D. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 COORDINATION

A. Site:
   1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other trades.
   2. If installation without coordination causes interference with work of other trades, Controls Contractor will correct conditions without extra charge.
   3. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

B. Test and Balance:

1. Provide Test and Balance Contractor a single set of necessary tools to interface to control system for testing and balancing.
2. Train Test and Balance Contractor to use control system interface tools.
3. Provide a qualified technician to assist with testing and balancing a minimum of the first 20 terminal units.
4. Test and Balance Contractor will return tools undamaged and in working condition at completion of testing and balancing.

C. Life Safety:
1. Duct smoke detectors required for air handler shutdown are provided under Division 28.
2. Interlock smoke detectors to air handlers for shutdown as specified on the Drawings.
3. Smoke dampers and actuators required for duct smoke isolation are provided under Division 23.
4. Interlock smoke dampers to air handlers as specified on the Drawings.
5. Fire and smoke dampers and actuators required for fire-rated walls are provided under Division 23.
6. Fire and smoke damper control is provided under Division 28.

D. Coordination with Other Controls:
1. Integrate with and coordinate controls and control devices furnished or installed by others as follows:
   a. Integration and operator interface software and hardware will be provided by the Integration Contractor, as specified in Division 25.
   b. Integration Contractor will be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.
   c. Communication media and equipment will be provided as specified in on the Drawings.
   d. Each supplier of a controls product will configure, program, start up, and test that product to meet the sequences of operation described on the Drawings, regardless of where within the contract documents those products are described.
   e. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.

3.4 GENERAL WORKMANSHIP

A. Install equipment, piping, and wiring or raceway horizontally, vertically, and parallel to walls wherever possible.

B. Provide sufficient slack and flexible connections to allow for piping and equipment vibration isolation.

C. Install equipment in readily accessible locations as defined by National Electrical Code (NEC) Chapter 1 Article 100 Part A.

D. Verify wiring integrity to ensure continuity and freedom from shorts and ground faults.

E. Equipment, installation, and wiring will comply with industry specifications and standards and local codes for performance, reliability, and compatibility.

3.5 FIELD QUALITY CONTROL

A. Work, materials, and equipment will comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in the Drawings.

B. Continually monitor field installation for code compliance and workmanship quality.

C. Controls Contractor will arrange for work inspection by the Owner.

3.6 EXISTING EQUIPMENT

A. Interconnecting control wiring to be removed will become Controls Contractor's property unless specifically noted or shown to be reused.

B. Existing control panels not scheduled for reuse will be removed and delivered to owner.

C. Unless otherwise directed, Controls Contractor is not responsible for repair or replacement of existing energy equipment and systems, valves, dampers, or actuators. Notify Engineer in writing immediately of existing equipment that requires maintenance.

D. Ensure proper operation of indicator gauges. Recalibrate gauges for reasonable accuracy or replace if calibration cannot bring accuracy into acceptable tolerance.

E. Deliver the following to owner if project includes new replacements:
1. Existing room thermostats.
2. Existing sensors and transmitters.
3. Existing controllers and auxiliary electronic devices.
4. Existing damper actuators, linkages, and appurtenances.
5. Existing control valves.

F. Existing mechanical system may be disabled temporarily for work to be performed during the project. A request for equipment downtime must be made to owner at least seven (7) days prior to work that is to be performed. Execution of work may not commence without approval from owner.

G. Maintain fan scheduling using existing or temporary time clocks or control systems throughout the control system installation.

H. Modify existing starter control circuits if necessary, to provide hand-off-auto control of each controlled starter. Furnish new starters or starter control packages as required.

I. Patch holes and finish to match existing walls.

J. At owner's request, items not to be delivered to owner will instead be properly disposed of. Hazardous materials will be disposed of under Division 02.

3.7 WIRING

A. Control and interlock wiring and installation will comply with national and local electrical codes, Division 26, and manufacturer's recommendations.

B. NEC Class 1 (line voltage) wiring will be UL listed in approved raceway as specified by NEC and Division 26.

C. Low-voltage wiring will meet NEC Class 2 requirements. Subfuse low-voltage power circuits as required to meet Class 2 current limit.

D. NEC Class 2 (current-limited) wires not in raceway but in concealed and accessible locations such as return air plenums will be UL listed for the intended application.

E. Install wiring in raceway where subject to mechanical damage and at levels below 10ft in mechanical, electrical, or service rooms and above hard ceilings or over large pieces of equipment.

F. Install Class 1 and Class 2 wiring in separate raceways. Boxes and panels containing high- voltage wiring and equipment will not be used for low-voltage wiring except for the purpose of interfacing the two through relays and transformers.

G. Do not install wiring in raceway containing tubing.

H. Do not splice wires between devices and controllers. A single, continuous wire must be used.

I. Use of wire nuts are not permitted. Wiring will be terminated or connected using terminals.

J. Class 2 wiring that is unable to be installed in raceways will be installed above ductwork and equipment at the highest point possible, run parallel or perpendicular to a surface, and supported at (5 ft.) intervals.

K. Use structural members to support or anchor plenum cables without raceway. Do not use ductwork, electrical raceways, piping, or ceiling suspension systems to support or anchor cables.

L. Anchored cables will be supported by J-Hooks or bridle rings. The use of cable ties is not permitted.

M. Secure raceways with raceway clamps fastened to structure and spaced according to code requirements. Raceways and pull boxes will not be hung on or attached to ductwork, electrical raceways, piping, or ceiling suspension systems.

N. Size raceway and select wire size and type in accordance with manufacturer's recommendations and NEC requirements.

O. Include one pull string in each raceway 2.5 cm (1 in.) or larger.

P. Use color-coded conductors throughout.

Q. Locate control and status relays in designated enclosures only. Do not install control and status relays in packaged equipment control panel enclosures containing Class 1 starters.

R. Conceal raceways except within mechanical, electrical, or service rooms. Maintain minimum clearance of 15 cm (6 in.) between raceway and high-temperature equipment.

S. Adhere to requirements in Division 26 where raceway crosses building expansion joints.

T. Install insulated bushings on raceway ends and enclosure openings. Seal top ends of vertical raceways.

U. Terminate control and interlock wiring related to the work of this section. Maintain at the job site updated (as-built) wiring diagrams that identify terminations.

V. Flexible metal raceways and liquid-tight flexible metal raceways will not exceed 1 m (3 ft.) in length and will be supported at each end. Do not use flexible metal raceway less than ½ in. electrical trade size. Use liquid-tight flexible metal raceways in areas exposed to moisture including chiller and boiler rooms.

W. Install raceway rigidly, support adequately, ream at both ends, and leave clean and free of obstructions. Join raceway sections with couplings and according to code. Make terminations in boxes with fittings. Make terminations not in boxes with bushings.

3.8 COMMUNICATION WIRING

A. Communication wiring will be low-voltage Class 2 wiring and will comply with the sequence of operations in the Drawings.

B. Existing communication wiring will not be reused, unless otherwise specified by owner.
   1. If communication wiring is to be reused, it will be the responsibility of the Controls Contractor to verify existing wiring adheres to the medium and topology requirements of the selected communication protocol.

C. Install communication wiring in separate raceways and enclosures from other Class 2 wiring.

D. During installation do not exceed maximum cable pulling, tension, or bend radius specified by the cable manufacturer.

E. Verify entire network's integrity following cable installation using appropriate tests for each cable.

F. Install lightning arrestor according to manufacturer's recommendations between cable and ground where a cable enters or exits a building.

G. Each run of communication wiring will be a continuous length without splices when that length is commercially available. Splices in communication wiring are not permitted.

H. Label communication wiring to indicate origination and destination.

I. Ground coaxial cable according to NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

J. BACnet MS/TP communications wiring will be installed in accordance with ASHRAE/ANSI Standard 135-2016. This includes but is not limited to:

1. The network will use shielded, twisted-pair cable with characteristic impedance between 100 and 130 ohms. Distributed capacitance between conductors will be less than 100 pF per meter (30 pF per foot.).
2. Network topology for BACnet MS/TP will be daisy chain only with a maximum unit load count of 32 per network segment. Other networking topologies and T taps are not permitted.
3. Additional unit loads may not be accommodated using repeaters.
4. The maximum length of an MS/TP segment is 1200 meters (4000 ft.) with AWG 18 cable and a maximum baud rate of 76800. A baud rate of 115200 will reduce to recommended maximum length of an MS/TP segment to 1000 meters (3280 ft.) The use of greater distances and/or different wire gauges must comply with the electrical specifications of EIA-485.
5. The maximum number of unit loads per segment will be 32, as specified in the EIA 485 standard. Additional unit loads may not be accommodated using repeaters.

3.9 FIBER OPTIC CABLE

A. During installation do not exceed maximum pulling tensions specified by cable manufacturer. Post-installation residual cable tension will be within cable manufacturer's specifications.

B. Install cabling and associated components according to manufacturers' instructions. Do not exceed minimum cable and unjacketed fiber bend radii specified by cable manufacturer.

3.10 INSTALLATION OF SENSORS

A. Install sensors according to manufacturer's recommendations.

B. Mount sensors rigidly and adequately for operating environment.

C. Install room temperature sensors on concealed junction boxes properly supported by wall framing.

D. 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.

E. Use averaging sensors in mixing plenums and hot and cold decks. Install averaging sensors in a serpentine manner vertically across duct. Support each bend with a capillary clip.

F. Install mixing plenum low-limit sensors in a serpentine manner horizontally across duct. Support each bend with a capillary clip. Provide 3 m (1 ft.) of sensing element for each 1 m 2 (1 ft2) of coil area.

G. Install pipe-mounted temperature sensors in wells. Install liquid temperature sensors with heat- conducting fluid in thermal wells.

H. Install outdoor air temperature sensors on north wall at designated location with sun shield.

I. Differential Air Static Pressure:
1. Piping to pressure transducer pressure ports will contain a capped test port adjacent to transducer.
2. Supply and return duct static pressure sensors will pipe the high-pressure tap to the duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
3. Building static pressure sensors will pipe the pressure sensor's low-pressure port to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe high-pressure port to a location behind a thermostat cover.
4. Pressure transducers, except those controlling VAV boxes, will be in control panels, not on monitored equipment or on ductwork. Mount transducers in a vibration- free location accessible for service without use of ladders or special equipment.

J. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before tee for water gauges.

K. Smoke detectors, freezestats, high-pressure cut-offs, and other safety switches will be hard-wired to de-energize equipment as described in the sequence of operation. Switches will require manual reset. Provide contacts that allow DDC software to monitor safety switch status.

L. Install discharge air temperature sensors far enough downstream of heaters to demonstrate accurate results free of stratification and hunting.

3.11 FLOW SWITCH INSTALLATION

A. Adjust flow switch according to manufacturer's instructions.

3.12 FLOW SENSOR INSTALLATION

A. Use correct sensor for application per manufacturers recommendations.

B. Calibrate flow sensor according to manufacturer's instructions.

3.13 ACTUATORS

A. Mount actuators and adapters according to manufacturer's recommendations.

B. Actuators requiring adaptors must use adaptors approved by the manufacturer.

C. Electric and electronic damper actuators will be mounted directly on damper shaft or jackshaft unless shown as a linkage installation. Link actuators according to manufacturer's recommendations.

D. For low-leakage dampers with seals, mount actuator with a minimum 5° travel available for damper seal tightening.

E. To compress seals when spring-return actuators are used on normally closed dampers, power actuators to approximately 5° open position, manually close the damper, and then tighten linkage.

F. Check operation of damper-actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.

G. Provide necessary mounting hardware and linkages for actuator installation.

3.14 WARNING LABELS

A. Affix permanent warning labels to equipment that can be automatically started by the control system.
   1. Labels will use white lettering (12-point type or larger) on a red background.
   2. Warning labels will read as follows.

C A U T I O N
This equipment is operating under automatic control and may start or stop at anytime without warning. Switch disconnect to "Off" position before servicing.

B. Affix permanent warning labels to motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.
   1. Labels will use white lettering (12-point type or larger) on a red background.
   2. Warning labels will read as follows.

C A U T I O N
This equipment is fed from more than one power source with separate disconnects. Disconnect power sources before servicing.

3.15 IDENTIFICATION OF HARDWARE AND WIRING

A. Label wiring and cabling, including that within factory-fabricated panels, with control system address or termination number at each end within 5 cm (2 in.) of termination.

B. Label pneumatic tubing at each end within 5 cm (2 in.) of termination with a descriptive identifier.

C. Permanently label or code each point of field terminal strips to show instrument or item served.

D. Label control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.

E. Label each control component with a permanent label. Label plug-in components such that labels remain stationary during component replacement.

F. Label room sensors related to terminal boxes or valves with nameplates.

G. Manufacturers' nameplates and UL or CSA labels will be visible and legible after equipment is installed.

H. Label identifiers will match record documents.

3.16 PROGRAMMING

A. Devices and objects will adhere to the object naming standard referenced in Appendix A of Division 25.

B. Programming will provide actions for each situation. Graphic- or parameter- based programs will be documented. Text-based programs will be modular, structured, and commented to clearly describe each section of the program.

C. Programs will adhere to sequences of operation specified in the Drawings. Program documentation or comment statements will reflect language used in sequences of operation.

3.17 CONTROL SYSTEM CHECKOUT AND TESTING

A. Complete startup testing to verify operational control system before notifying owner of system demonstration. Provide owner with schedule for startup testing. Owner or a consultant on behalf of owner must be present during startup testing.
   1. Controls Contractor will collaborate with owner and/or a consultant on behalf of owner during the commissioning process.
   2. Calibrate and prepare for service each instrument, control, and accessory equipment.
   3. Verify that control wiring is properly connected and free of shorts and ground faults. Verify that terminations are tight.
   4. Enable control systems and verify each input device's calibration. Calibrate each device according to manufacturer's recommendations.
   5. Verify that binary output devices such as relays, solenoid valves, two-position actuators and control valves, and magnetic starters, operate properly and that normal positions are correct.

6. Verify that analog output devices such as I/Ps and actuators are functional, that start and span are correct, and that direction and normal positions are correct. Check control valves and automatic dampers to ensure proper action and closure. Make necessary adjustments to valve stem and damper blade travel.
7. Prepare a log documenting startup testing of each input and output device, with technician's initials certifying each device has been tested and calibrated.
8. Verify that system operates according to sequences of operation. Simulate and observe each operational mode by overriding and varying inputs and schedules. Tune PID loops and each control routine that requires tuning for minimum overshoot (<10%) and maximum response.
9. Check each alarm with an appropriate signal at a value that will trip the alarm.
10. Trip interlocks using field contacts to check logic and to ensure that actuators fail in the proper direction.
11. Test interlock actions by simulating alarm conditions to check initiating value of variable and interlock action.

3.18 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

A. Prior to acceptance, perform the following performance tests to demonstrate system operation and compliance with specification after and in addition to tests specified. Provide Engineer with log documenting completion of startup tests.
   1. Engineer will be present to observe and review system demonstration. Notify Engineer at least 10 days before system demonstration begins.
   2. Complete approved checklists and forms for each system as part of system demonstration.
   3. Demonstrate actual field operation of each sequence of operation as specified in the Drawings. Provide at least two persons equipped with two-way communication. Demonstrate calibration and response of input and output points requested by Engineer. Provide and operate test equipment required to prove proper system operation.
   4. Demonstrate compliance with sequences of operation through each operational mode.
   5. Demonstrate complete operation of operator interface.
   6. Demonstrate each of the following:
      a. DDC loop response. Supply graphical trend data output showing each DDC loop's response to a setpoint change representing an actuator position change of at least 25% of full range. Trend sampling rate will be from 10 seconds to 3 minutes, depending on loop speed. Each sample's trend data will show setpoint, actuator position, and controlled variable values. Engineer will require further tuning of each loop that displays unreasonably under- or over-damped control.
      b. Demand limiting. Supply trend data output showing demand-limiting algorithm action. Trend data will document action sampled each minute over at least a 30-minute period and will show building kW, demand-limiting setpoint, and status of setpoints and other affected equipment parameters.
      c. Building fire alarm system interface.

d. Trend logs for each system. Trend data will indicate setpoints, operating points, valve positions, and other data as specified in the points list provided with each sequence of operation in the Drawings. Functional test logs will cover three 48-hour periods. Logs will be accessible through system's operator interface and will be retrievable for use from each field device as specified in Division 25.

7. Tests that fail to demonstrate proper system operation will be repeated after Controls Contractor makes necessary repairs or revisions to hardware or software to successfully complete each test.

B. Acceptance.

1. After tests described in this specification are performed to the satisfaction of both Engineer and owner, Engineer will accept control system as meeting completion requirements. Engineer may exempt tests from completion requirements that cannot be performed due to circumstances beyond Controls Contractor's control. Engineer will provide written statement of each exempted test. Exempted tests will be performed as part of warranty.

2. System will not be accepted until completed demonstration forms and checklists are submitted and approved as required in the Drawings and trend logs created for the purpose of system demonstration and commissioning are disabled and trend data from the disabled trend logs are purged from the building management system.

3.19 CLEANING

A. Each day clean up debris resulting from work. Remove packaging material as soon as its contents have been removed. Collect waste and place in designated location.

B. On completion of work in each area, clean work debris and equipment. Keep areas free from dust, dirt, and debris.

C. On completion of work, check equipment furnished under this section for paint damage. Repair damaged factory-finished paint to match adjacent areas. Replace deformed cabinets and enclosures with new material and repaint to match adjacent areas.

END OF SECTION

APPENDIX A – STABILITY AND ACCURACY TABLES

TABLE 1: REPORTING ACCURACY

Measured Variable	**Reported Accuracy**
Space Temperature	±0.5ºC (±1ºF)
Ducted Air	±0.5ºC (±1ºF)
Outside Air	±1.0ºC (±2ºF)
Dew Point	±1.5ºC (±3ºF)
Water Temperature	±0.5ºC (±1ºF)
Delta-T	±0.15ºC (±0.25ºF)
Relative Humidity	±5% RH
Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2)
Electrical (A, V, W, Power Factor)	±1% of reading (see Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO_2)	±50 ppm

Note 1: Accuracy applies to 10% - 100% of scale
Note 2: For both absolute and differential pressure
Note 3: Not including utility-supplied meters

TABLE 2: CONTROL STABILITY AND ACCURACY

Controlled Variable	**Control Accuracy**	**Range of Medium**
Air Pressure	±50 Pa (±0.2 in. w.g.) ±3 Pa (±0.01 in. w.g.)	0-1.5 kPa (0-6 in. w.g.) -25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±1.0ºC (±2.0ºF)	
Duct Temperature	±1.5ºC (±3ºF)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in. w.g.)	MPa (1-150 psi) 0-12.5 kPa (0-50 in. w.g.) differential

APPENDIX B – CONDUCTOR REQUIREMENTS TABLES

TABLE 1: WIRE INFORMATION

USAGE	SHEATH COLOR	GAGE/QTY	SHIELDED	PLENUM RATED	WCW Part Number
Analog Inputs	Yellow	18-2	Yes	Yes	WCW-18/2YEL-WC
Analog Inputs	Yellow	18-3	Yes	Yes	WCW-18/3YEL-WC
Analog Outputs	Tan	18-2	Yes	Yes	WCW-18/2TAN-WC
Analog Outputs	Tan	18-3	Yes	Yes	WCW-18/3TAN-WC
Binary Inputs	Orange	18-2	Yes	Yes	WCW-18/2ORG-WC
Binary Outputs	Violet	18-2	Yes	Yes	WCW-18/2VLT-WC
24v Power	White with Red Stripe	18-2	No	Yes	002361
24v Power	White with Blue Stripe	16-2	No	Yes	001362
24v Power	White with Yellow Stripe	14-2	No	Yes	007963
FC Bus	Yellow with Blue Stripe	22-3	Yes	Yes	0043339
SA Bus	Brown	22-2P	Yes	Yes	WCW-22/2P-SA-PLN
IP Comm	Purple	23-4P	No	Yes	5566050A
IP Stats	Orange	23-4P	No	Yes	5566040A

Note: The Windy City Wire Part Number is the basis of design. Comparable cables from other manufacturers may be acceptable.

SECTION 23 11 23

FACILITY NATURAL GAS PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
  1. Pipes, tubes, and fittings.
  2. Piping specialties.
  3. Piping and tubing joining materials.
  4. Valves.
  5. Manual gas shutoff valves.
  6. Pressure regulators.
  7. Dielectric fittings

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product indicated provide materials of construction, pressure ratings, capacities, electrical requirements, and dimensions.
  1. Piping specialties.
  2. Corrugated, stainless-steel tubing with associated components.
  3. Valves. Include pressure rating, capacity, settings, and electrical connection data of selected models.
  4. Pressure regulators. Indicate pressure ratings and capacities.
  5. Dielectric fittings.

B. Shop Drawings: For facility natural-gas piping layout. Include plans, piping layout and elevations, sections, and details for fabrication of pipe anchors, hangers, supports for multiple pipes, alignment guides, expansion joints and loops, and attachments of the same to building structure. Detail location of anchors, alignment guides, and expansion joints and loops.

1.3 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.4 QUALITY ASSURANCE

A. Steel Support 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.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

1.5 COORDINATION

A. 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 Architect not less than two days in advance of proposed utility interruptions.
   2. Do not proceed with utility interruptions without Architect’s written permission.
   3. Coordinate sizes and locations of concrete bases with actual equipment provided.
   4. Coordinate requirements for access panels and doors for valves installed concealed behind finished surfaces.

PART 2 - PRODUCTS

2.1 PERFORANCE REQUIREMENTS

A. Minimum Operating-Pressure Ratings:
   1. Piping and Valves: 100 psig minimum unless otherwise indicated.
   2. Service Regulators: 65 psig minimum unless otherwise indicated.

B. Natural-Gas System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 0.5 psig but not more than 2 psig, and is reduced to secondary pressure of 0.5 psig or less.

2.2 PIPES, TUBES, AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
   1. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.
   2. Wrought-Steel Welding Fittings: ASTM A 234/A 234M for butt welding and socket welding.
   3. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.
   4. Cast-Iron Flanges and Flanged Fittings: ASME B16.1, Class 125, raised ground face, and bolt holes.
   5. Steel Flanges and Flanged Fittings: ASME B16.5.
   6. Gasket Material: Asbestos free, thickness, material, and type suitable for natural gas.
   7. Protective Coating for Underground Piping:
      a. Piping:
         1) Manufacturer and Product: Subject to compliance with requirements, provide 3M Extrucoat or approved equal.

b. Fittings and Joints:
1) Manufacturer and Product: Subject to compliance with requirements, provide Tyco Adhesives Polyken #1027 primer and #930-35 tape or approved equal.
2) Primer: Rubber adhesive primer.
3) Tape: Minimum 35 mils thick polyethylene tape with butyl adhesive on one side.

B. Corrugated, Stainless-Steel Tubing: Comply with ANSI/IAS LC 1.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
a. OmegaFlex, Inc.
b. Parker Hannifin Corporation; Parflex Division.
c. Titeflex.
d. Tru-Flex Metal Hose Corp.
2. Tubing: ASTM A 240/A 240M, corrugated, Series 300 stainless steel.
3. Coating: PE with flame retardant.
a. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
1) Flame-Spread Index: 25 or less.
2) Smoke-Developed Index: 50 or less.
4. Fittings: Copper-alloy mechanical fittings with ends made to fit and listed for use with corrugated stainless-steel tubing and capable of metal-to-metal seal without gaskets. Include brazing socket or threaded ends complying with ASME B1.20.1.
5. Striker Plates: Steel, designed to protect tubing from penetrations.
6. Manifolds: Malleable iron or steel with factory-applied protective coating. Threaded connections shall comply with ASME B1.20.1 for pipe inlet and corrugated tubing outlets.
7. Operating-Pressure Rating: 5 psig.

C. 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. PE Transition Fittings: Factory-fabricated fittings with PE pipe complying with ASTM D 2513, SDR 11; and steel pipe complying with ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
3. 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 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.

D. Transition Service-Line Risers: Factory fabricated and leak tested.

1. Underground Portion: PE pipe complying with ASTM D2513, SDR 11 inlet connected to steel pipe complying with ASTM A53/A53M, Schedule 40, Type E or S, Grade B, with corrosion-protective coating for aboveground outlet.
2. Outlet shall be threaded or flanged or suitable for welded connection.
3. Bridging sleeve over mechanical coupling.
4. Factory-connected anode.
5. Tracer wire connection.
6. Ultraviolet shield.
7. Stake supports with factory finish to match steel pipe casing or carrier pipe.

E. Plastic Mechanical Couplings, NPS 1-1/2 and Smaller: Capable of joining PE pipe to PE pipe.

1. PE body with molded-in, stainless-steel support ring.
2. Buna-nitrile seals.
3. Acetal collets.
4. Electro-zinc-plated steel stiffener.

F. Plastic Mechanical Couplings, NPS 2 and Larger: Capable of joining PE pipe to PE pipe, steel pipe to PE pipe, or steel pipe to steel pipe.

1. Fiber-reinforced plastic body.
2. PE body tube.
3. Buna-nitrile seals.
4. Acetal collets.
5. Stainless-steel bolts, nuts, and washers.

G. Steel Mechanical Couplings: Capable of joining plain-end PE pipe to PE pipe, steel pipe to PE pipe, or steel pipe to steel pipe.

1. Stainless-steel flanges and tube with epoxy finish.
2. Buna-nitrile seals.
3. Stainless-steel bolts, washers, and nuts.
4. Factory-installed anode for steel-body couplings installed underground.

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 A126, 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: 40-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 125 psig

D. 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 natural gas.

B. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

C. Brazing Filler Metals: Alloy with melting point greater than 1000 deg F complying with AWS A5.8/A5.8M. Brazing alloys containing more than 0.05 percent phosphorus are prohibited.

2.5 MANUAL GAS SHUTOFF VALVES

A. See "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles 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. Dryseal Threads on Flare Ends: Comply with ASME B1.20.3.
4. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
5. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction for valves 1 inch and smaller.

6. Service Mark: Valves 1-1/4 inches to NPS 2 shall have initials "WOG" permanently marked on valve body.

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. Two-Piece, Full-Port, Bronze Ball Valves with Bronze Trim: MSS SP-110.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. BrassCraft Manufacturing Company; a Masco company.
      b. Conbraco Industries, Inc.; Apollo Div.
      c. Lyall, R. W. & Company, Inc.
      d. McDonald, A. Y. Mfg. Co.
      e. Perfection Corporation; a subsidiary of American Meter Company
   2. Body: Bronze, complying with ASTM B 584.
   3. Ball: Chrome-plated bronze.
   4. Stem: Bronze; blowout proof.
   5. Seats: Reinforced TFE; blowout proof.
   6. Packing: Threaded-body packnut design with adjustable-stem packing.
   7. Ends: Threaded.
   8. CWP Rating: 600 psig.
   9. Listing: Valves NPS 1 and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   10. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

E. Bronze Plug Valves: MSS SP-78.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Lee Brass Company.
      b. McDonald, A. Y. Mfg. Co.
   2. Body: Bronze, complying with ASTM B 584.
   3. Plug: Bronze.
   4. Ends: Threaded.
   5. Operator: Square head or lug type with tamperproof feature where indicated.
   6. Pressure Class: 125 psig.
   7. Listing: Valves NPS 1 and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   8. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

F. Cast-Iron Lubricated Plug Valves: MSS SP-78.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Davis Valve.
      b. Hamestead Valve Div.
      c. McDonald, A. Y. Mfg Co.
      d. Olson Technologies, Inc.
   2. Body: Cast-iron, complying with ASTM A126-B.
   3. Plug: Cast-iron, complying with ASTM A126-B.
   4. Ends: Flanged complying with ASME B16.5.
   5. Operator: Square head or lug type with tamperproof feature where indicated.
   6. Pressure Class: 125 psig.
   7. Lubricant: Suitable for natural gas.
   8. Service: Suitable for natural-gas service.

G. PE Ball Valves: Comply with ASME B16.40.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Kerotest Manufacturing Corp.
      b. Lyall, R. W. & Company, Inc.
      c. Perfection Corporation; a subsidiary of American Meter Company.
   2. Body: PE.
   3. Ball: PE.
   4. Stem: Acetal.
   5. Seats and Seals: Nitrile.
   6. Ends: Plain or fusible to match piping.
   7. CWP Rating: 80 psig.
   8. Operating Temperature: Minus 20 to plus 140 deg F.
   9. Operator: Nut or flat head for key operation.
   10. Include plastic valve extension.
   11. Include tamperproof locking feature for valves where indicated on Drawings.

H. Valves Boxes:
   1. Cast-iron, two-section box.
   2. Top section with cover with "GAS" lettering.
   3. Bottom section with base to fit over valve and barrel a minimum of 5 inches in diameter.
   4. Adjustable cast-iron extensions of length required for depth of bury.
   5. Include tee-handle, steel operating wrench with socket end fitting valve nut or flat head, and with stem of length required to operate valve.

2.6 MOTORIZED GAS VALVES

A. Electrically Operated Valves: Comply with UL 429.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. ASCO Power Technologies, LP; Division of Emerson.
   b. Dungs, Karl, Inc.
   c. Eclipse Combustion, Inc.
   d. Goyen Valve Corp.; Tyco Environmental Systems.
   e. Magnatrol Valve Corporation.
   f. Parker Hannifin Corporation; Climate & Industrial Controls Group; Skinner Valve Div.
   g. Watts Regulator Co.; Division of Watts Water Technologies, Inc.
2. Pilot operated.
3. Body: Brass or aluminum.
4. Seats and Disc: Nitrile rubber.
5. Springs and Valve Trim: Stainless steel.
6. 120-V ac, 60 Hz, Class B, continuous-duty molded coil, and replaceable.
7. NEMA ICS 6, Type 4, coil enclosure.
8. Normally closed.
9. Visual position indicator.

2.7 EARTHQUAKE VALVES

A. Earthquake Valves: Comply with ASCE 25.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Vanguard Valves, Inc.
   2. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   3. Maximum Operating Pressure: 5 psig.
   4. Cast-aluminum body with nickel-plated chrome steel internal parts.
   5. Nitrile-rubber valve washer.
   6. Sight windows for visual indication of valve position.
   7. Threaded end connections complying with ASME B1.20.1.
   8. Wall mounting bracket with bubble level indicator.

B. Earthquake Valves: Comply with ASCE 25.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Pacific Seismic Products, Inc.
   2. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   3. Maximum Operating Pressure: 7 psig.
   4. Cast-aluminum body with stainless-steel internal parts.
   5. Nitrile-rubber, reset-stem o-ring seal.
   6. Valve position, open or closed, indicator.
   7. Composition valve seat with clapper held by spring or magnet locking mechanism.

8. Level indicator.
9. End Connections: Threaded for valves NPS 2 and smaller.

2.8 PRESSURE REGULATOR

A. General Requirements:
   1. Single stage and suitable for natural gas.
   2. Steel jacket and corrosion-resistant components.
   3. Elevation compensator.
   4. End Connections: Threaded for regulators NPS 2 and smaller.

B. Line Pressure Regulators: Comply with ANSI Z21.80.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. American Meter Company.
      b. Fisher Control Valves and Regulators; Division of Emerson Process Management.
      c. Invensys.
      d. Maxitrol Company.
   2. Body and Diaphragm Case: Cast iron or die-cast aluminum.
   3. Springs: Zinc-plated steel; interchangeable.
   4. Diaphragm Plate: Zinc-plated steel.
   5. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
   6. Orifice: Aluminum; interchangeable.
   7. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
   8. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
   9. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.
   10. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
   11. Maximum Inlet Pressure: 10 psig.

C. Appliance Pressure Regulators: Comply with ANSI Z21.18.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Eaton Corporation; Controls Div.
      b. Harper Wyman Co.
      c. Maxitrol Company.
      d. SCP, Inc.
   2. Body and Diaphragm Case: Die-cast aluminum.
   3. Springs: Zinc-plated steel; interchangeable.
   4. Diaphragm Plate: Zinc-plated steel.
   5. Seat Disc: Nitrile rubber.

6. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
7. Factory-Applied Finish: Minimum three-layer polyester and polyurethane paint finish.
8. Regulator may include vent limiting device, instead of vent connection, if approved by authorities having jurisdiction.
9. Maximum Inlet Pressure: 5 psig.

2.9 DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

B. Dielectric Unions:
   1. Standard: ASSE 1079.
   2. Pressure Rating: 125 psig minimum at 180 deg F .
   3. End Connections: Solder-joint copper alloy and threaded ferrous.

C. Dielectric Flanges:
   1. Standard: ASSE 1079.
   2. Factory-fabricated, bolted, companion-flange assembly.
   3. Pressure Rating: 125 psig minimum at 180 deg F.
   4. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

D. Dielectric-Flange Insulating Kits:
   1. Nonconducting materials for field assembly of companion flanges.
   2. Pressure Rating: 150 psig
   3. Gasket: Neoprene or phenolic.
   4. Bolt Sleeves: Phenolic or polyethylene.
   5. Washers: Phenolic with steel backing washers.

2.10 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 inscribed 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 OUTDOOR PIPING INSTALLATION

A. Comply with NFPA 54, the Arizona State Plumbing Code, and the International Fuel Gas Code for installation and purging of natural-gas piping.

B. Extend natural-gas piping to meter location.
   1. Gas service piping from utility main to meter, including service pressure regulator and service meter will be provided by gas utility. Coordinate location and schedule with gas utility.

C. Install underground, natural-gas piping buried at least 18 inches below finished grade. Comply with requirements in Division 02 for excavating, trenching, and backfilling.
   1. If natural-gas piping is installed less than 18 inches below finished grade, install it in containment conduit.

D. Install underground, PE, natural-gas piping according to ASTM D 2774.

E. Steel Piping with Protective Coating:
   1. Field Applied Tape:
      a. Apply to joints, fittings and other areas where the factory applied coating is missing or damaged.
      b. Apply to clean and dry surfaces.
      c. Apply adhesive primer prior to application of tape.
      d. Wrap tape with minimum 50 percent overlap.
      e. Extend tape a minimum of 4 inches over intact, factory-applied coating.

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

G. Install schedule 40 PVC pipe sleeve for pipe installed under paved walks or driveways, extend 18 inches beyond edge of paving.

H. Exterior-Wall Pipe Penetrations: Seal penetrations using steel or cast-iron pipe sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.
   1. See Division 22 Section 22 05 15 “Common Work Results for Plumbing” for sleeve and mechanical sleeve seals.

3.2 INDOOR PIPING INSTALLATION

A. Comply with NFPA 54, the Arizona State Plumbing Code and the International Fuel Gas Code for installation and purging of natural-gas piping.

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

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 at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

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

G. Locate valves for easy access.

H. Install natural-gas piping at uniform grade of 0.1 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. 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 in Division 07.

L. Verify final equipment locations for roughing-in.

M. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.

N. Drips and Sediment Traps: Install drips at points where condensate may collect, including service-meter outlets. Locate where accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.
   1. Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Use nipple a minimum length of 3 pipe diameters, but not less than 3 inches long and same size as connected pipe. Install with space below bottom of drip to remove plug or cap.

O. Extend relief vent connections for service regulators, line regulators, and overpressure protection devices to outdoors and terminate with weatherproof vent cap or turned-down, reducing-elbow fittings with corrosion-resistant insect screen in large end.

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 natural-gas piping and piping installed under the building in containment conduit constructed of steel pipe with welded joints. Install a vent pipe from containment conduit to outdoors and terminate with weatherproof vent cap.
   1. Above Accessible Ceilings: Natural-gas piping, fittings, valves, and regulators may be installed in accessible spaces without containment conduit.

2. In Floors: Install natural-gas 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 natural-gas 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.
5. Exception: Tubing passing through partitions or walls does not require striker barriers.
6. Prohibited Locations:
7. Do not install natural-gas piping in or through circulating air ducts, clothes or trash chutes, chimneys or gas vents (flues), ventilating ducts, or dumbwaiter or elevator shafts.
8. Do not install natural-gas piping in solid walls or partitions.

R. Install corrugated, stainless-steel tubing according to manufacturer’s written instructions. Include striker plates to protect tubing from puncture where tubing is restrained and cannot move.

S. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.

T. Connect branch piping from top or side of horizontal piping.

U. Install unions in pipes NPS 2 and smaller, adjacent to each valve, at final connection to each piece of equipment. Unions are not required on flanged devices.

V. Install flanges on valves, specialties, and equipment having NPS 2-1/2 and larger connections.

W. Do not use natural-gas piping as grounding electrode.

X. Install strainer on inlet of each line-pressure regulator and automatic or electrically operated valve.

Y. Install pressure gage downstream from each line regulator.

Z. Install sleeves for piping penetrations of walls, ceilings, and floors.

AA. Install sleeve seals for piping penetrations of concrete walls and slabs.

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

3.3 VALVE INSTALLATION

A. Install manual gas shutoff valve for each gas appliance ahead of corrugated stainless-steel tubing.

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

3.4 PIPING JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs.

B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

C. Threaded Joints:
1. Thread pipe with tapered pipe threads complying with ASME B1.20.1.
2. Cut threads full and clean using sharp dies.
3. Ream threaded pipe ends to remove burrs and restore full inside diameter of pipe.
4. Apply appropriate tape or thread compound to external pipe threads unless dryseal threading is specified.
5. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

D. Welded Joints:
1. Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators.
2. Bevel plain ends of steel pipe.
3. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.

E. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter.

F. Flanged Joints: Install gasket material, size, type, and thickness appropriate for natural-gas service. Install gasket concentrically positioned.

G. Flared Joints: Cut tubing with roll cutting tool. Flare tube end with tool to result in flare dimensions complying with SAE J513. Tighten finger tight, then use wrench. Do not overtighten.

H. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D2657.

1. Plain-End Pipe and Fittings: Use butt fusion.
2. Plain-End Pipe and Socket Fittings: Use socket fusion.

3.5 HANGER AND SUPPORT INSTALLATION

A. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices.

B. Comply with requirements for pipe hangers and supports specified in Division 22 Section 22 05 29 "Hangers and Supports for Plumbing Piping and Equipment.

C. Install hangers for horizontal steel piping with the following maximum spacing and minimum rod sizes:
   1. NPS 1 and Smaller: Maximum span, 96 inches; minimum rod size, 3/8 inch.
   2. NPS 1-1/4: Maximum span, 108 inches; minimum rod size, 3/8 inch.
   3. NPS 1-1/2 and NPS 2: Maximum span, 108 inches; minimum rod size, 3/8 inch.
   4. NPS 2-1/2 to NPS 3-1/2: Maximum span, 10 feet; minimum rod size, ½ inch.
   5. NPS 4 and Larger: Maximum span, 10 feet; minimum rod size, 5/8 inch.

D. Install hangers for horizontal, corrugated stainless-steel tubing with the following maximum spacing and minimum rod sizes:
   1. NPS 3/8: Maximum span, 48 inches; minimum rod size, 3/8 inch.
   2. NPS 1/2: Maximum span, 72 inches; minimum rod size, 3/8 inch.
   3. NPS 3/4 and Larger: Maximum span, 96 inches; minimum rod size, 3/8 inch.

E. Support horizontal piping within 12 inches of each fitting.

F. Support vertical runs of steel piping to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

G. Support vertical runs of corrugated stainless-steel tubing to comply with manufacturer's written instructions, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

3.6 CONNECTIONS

A. Connect to utility's gas main according to utility's procedures and requirements.

B. Install natural-gas piping electrically continuous and bonded to gas appliance equipment grounding conductor of the circuit powering the appliance according to NFPA 70.

C. Install piping adjacent to appliances to allow service and maintenance of appliances.

D. Connect piping to appliances using manual gas shutoff valves and unions. Install valve within 72 inches of each gas-fired appliance and equipment. Install union between valve and appliances or equipment.

E. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.

3.7 LABELING AND IDENTIFYING

A. Comply with requirements in Division 22 Section 22 05 53 "Identification for Plumbing Piping and Equipment" for piping and valve identification.

B. Install detectable warning tape directly above gas piping, 12 inches below finished grade, except 6 inches below subgrade under pavements and slabs.

3.8 PAINTING

A. Paint exposed, exterior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components, with factory-applied paint or protective coating.

1. Alkyd System: MPI EXT 5.1D.

B. Paint exposed, interior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components, with factory-applied paint or protective coating.

1. Latex Over Alkyd Primer System: MPI INT 5.1Q.
2. Alkyd System: MPI INT 5.1E.

C. Damage and Touchup: Repair marred and damaged factory-applied finishes with materials and by procedures to match original factory finish.

3.9 CONCRETE BASES

A. Concrete Bases: Anchor equipment to concrete base

1. Construct concrete bases of dimensions indicated, but not less than 6 inches larger in both directions than supported unit.
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. Use 3000-psig 28-day, compressive-strength concrete and reinforcement.

3.10 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:
   1. Test, inspect, and purge natural gas according to NFPA 54, Arizona State Plumbing Code and the International Fuel Gas Code and authorities having jurisdiction.

C. Natural-gas piping will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

3.11 DEMONSTRATION

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

3.12 OUTDOOR PIPING SCHEDULE

A. Underground natural-gas piping shall be one of 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.
   2. Steel pipe with wrought-steel fittings and welded joints, or mechanical couplings. Coat pipe and fittings with protective coating for steel piping.

B. Aboveground natural-gas piping shall be one of the following:
   1. Steel pipe with malleable-iron fittings and threaded joints.
   2. Steel pipe with wrought-steel fittings and welded joints.

C. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.

3.13 INDOOR PIPING SCHEDULE

A. Aboveground, branch piping NPS 1 and smaller shall be one of the following:
   1. Corrugated stainless-steel tubing with mechanical fittings having socket or threaded ends to match adjacent piping.
   2. Steel pipe with malleable-iron fittings and threaded joints.

B. Aboveground, distribution piping shall be the following:
   1. NPS 3/4 through 1-1/2: Steel pipe with malleable-iron fittings and threaded joints.
   2. NPS 2 and Larger: Steel pipe with wrought-steel fittings and welded joints.

C. Underground, below building, piping shall be the following:
   1. NPS 3/4 through 1-1/2: Steel pipe with malleable-iron fittings and threaded joints.
   2. NPS 2 and Larger: Steel pipe with wrought-steel fittings and welded joints.

D. Containment Conduit: Schedule 40, steel pipe, minimum two pipe sizes larger than carrier pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping. Vent to exterior of building.

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.

3.14 UNDERGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

A. Connections to Existing Gas Piping: Use valve and fitting assemblies made for tapping utility's gas mains and listed by an NRTL

B. Underground: PE valves.

3.15 ABOVEGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

A. Valves at service meter shall be one of the following:
1. Pipe Sizes NPS 2 and Smaller:
2. Two-piece, full-port, bronze ball valves with bronze trim.
3. Bronze plug valve.
4. Pipe Sizes NPS 2-1/2 and Larger: Cast-iron lubricated plug valve.

B. Distribution piping valves shall be the following:
1. Pipe Sizes NPS 2 and Smaller:
2. Two-piece, full-port, bronze ball valves with bronze trim.
3. Bronze plug valve.
4. Pipe Sizes NPS 2-1/2 and Larger: Cast-iron lubricated plug valve.

C. Valves in branch piping for single appliance shall be one of the following:
1. Two-piece, full-port, bronze ball valves with bronze trim.
2. Bronze plug valve.

END OF SECTION

SECTION 23 21 13

HYDRONIC PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes pipe and fitting materials, joining methods, special-duty valves, and specialties for the following:
   1. Hot-water heating piping.
   2. Chilled-water piping.
   3. Condenser-water piping.
   4. Makeup-water piping.
   5. Blowdown-drain piping.
   6. Air-vent piping.
   7. Safety-valve-inlet and -outlet piping.

B. Related Requirements:
   1. See Section 23 21 14 "Pre-Insulated Piping" for underground piping and flushing and testing procedures for hydronic piping.
   2. See Section 23 21 23 "Hydronic Pumps" for pumps, motors, and accessories for hydronic piping.

1.2 ACTION SUBMITTALS

A. Product Data: For each type, application, and location of the following:
   1. Pipe
   2. Fittings
   3. Joining Materials
   4. Bypass chemical feeder
   5. Valves. Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.
   6. Air control devices.
   7. Hydronic specialties.

1.3 INFORMATIONAL SUBMITTALS

A. Delegated-Design Submittal:
   1. Design calculations and detailed fabrication and assembly of pipe anchors and alignment guides, hangers and supports for multiple pipes in parallel not scheduled in Paragraph 3.4, 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.
   4. Locations of and details for penetration and firestopping for fire- and smoke-rated wall and floor and ceiling assemblies.

B. Coordination Drawings: Piping layout, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
   1. Suspended ceiling components.
   2. Other building services.
   3. Structural members.
   4. Pipe elevation above floor or grade.
   5. Hydronic equipment.

C. Qualification Data: For Installer.

D. Welding certificates.

E. Field quality-control reports.

F. Preconstruction Test Reports:
   1. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project site.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code.

B. Installer Qualifications:
   1. Installers of Pressure-Sealed Joints: Installers shall be certified by pressure-seal joint manufacturer as having been trained and qualified to join piping with pressure-seal pipe couplings and fittings.

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

D. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.
2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature:

1. Chilled-Water Piping: 125 psig at 200ºF.
2. Condenser Water Piping: 125 psig at 150ºF.
3. Makeup-Water Piping: 80 psig at 150 deg F.
4. Blowdown-Drain Piping: 200 deg F.
5. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.
6. Air-Vent Piping: 125 psig at 200ºF.

2.2 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tubing: ASTM B 88, Type K.

B. Annealed-Temper Copper Tubing: ASTM B 88, Type K.

C. Wrought-Copper Fittings: ASME B16.22.

D. Wrought-Copper Unions: ASME B16.22.

2.3 STEEL PIPE AND FITTINGS

A. Steel Pipe:

1. NPS 2 and Smaller: ASTM A 53, Type S (seamless), Grade B, Schedule 40, black steel plain ends.
2. NPS 2-1/2 through 12: ASTM A 53, Type E (electric-resistance welded), Grade B, Schedule 40, black steel, plain ends.

B. Cast-Iron Threaded Fittings: ASME B16.4; Classes 125 and 250 as indicated in Part 3 "Piping Applications" Article.

C. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in Part 3 "Piping Applications" Article.

D. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in Part 3 "Piping Applications" Article.

E. Cast-Iron Pipe Flanges and Flanged Fittings: ASME B16.1, Classes 125, and 250; raised ground face, and bolt holes spot faced as indicated in Part 3 "Piping Applications" Article.

F. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
  1. Material Group: 1.1.
  2. End Connections: Butt welding.
  3. Facings: Raised face.

G. Wrought Cast- and Forged-Steel Welding Fittings: ASME B16.9 or ASME B 16.11.

H. Grooved Mechanical-Joint Fittings and Couplings:
  1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
     a. Anvil International, Inc.
     b. S. P. Fittings; a division of Star Pipe Products.
     c. Victaulic Company of America.
  2. Joint Fittings: ASTM A 536, Grade 65-45-12 ductile iron; ASTM A 47/A 47M, Grade 32510 malleable iron; ASTM A 53/A 53M, Type F, E, or S, Grade B fabricated steel; or ASTM A 106, Grade B steel fittings with grooves or shoulders constructed to accept grooved-end couplings; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.
  3. Couplings: Ductile- or malleable-iron housing and synthetic rubber gasket of central cavity pressure-responsive design; with nuts, bolts, locking pin, locking toggle, or lugs to secure grooved pipe and fittings.

2.4 PROTECTIVE COATING

A. Piping:
  1. Manufacturer and Product: Subject to compliance with requirements, provide 3M Extrucoat or approved equal.
  2. Coating: Factory applied, corrosion-resistant, minimum 2 mils thick, polyethylene coating for protection of steel piping in corrosive atmospheres or below ground.

B. Fittings and Joints:
  1. Manufacturer and Product: Subject to compliance with requirements, provide Tyco Adhesives Polyken #1027 primer and #930-35 tape or approved equal.
  2. Primer: Rubber adhesive primer.
  3. Tape: Minimum 35 mils thick polyethylene tape with butyl adhesive on one side.

2.5 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 thickness or specific material is indicated.
   2. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
   3. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.

B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.

C. Solder Filler Metals: ASTM B 32, 95-5 tin antimony. Include water-flushable flux according to ASTM B 813.

D. Brazing Filler Metals: AWS A5.8, BAg-1, silver alloy.

E. Gasket Material: Thickness, material, and type suitable for fluid to be handled and working temperatures and pressures.

2.6 VALVES

A. Gate, Check, Ball, and Butterfly Valves: Comply with requirements specified in Division 23 Section 23 05 23 "General Duty Valves for HVAC Piping."

B. Automatic Temperature-Control Valves, Actuators, and Sensors: Comply with requirements specified in Division 23 Section 23 09 23 "Instrumentation and Controls for HVAC."

C. Bronze, Calibrated, Balancing Valves.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Armstrong Pumps, Inc.
      b. Bell & Gossett Domestic Pump; a division of ITT Industries.
      c. Griswold Controls.
      d. Tour & Andersson; available through Victaulic Company of America
   2. Body: Bronze, ball or plug type with calibrated orifice or venturi.
   3. Ball: Brass or stainless steel.
   4. Plug: Resin.
   5. Seat: PTFE.
   6. End Connections: Threaded or socket.
   7. Pressure Gage Connections: Integral seals for portable differential pressure meter.
   8. Handle Style: Lever, with memory stop to retain set position.
   9. CWP Rating: Minimum 125 psig.
   10. Maximum Operating Temperature: 250 deg F.

D. Cast-Iron or Steel, Calibrated-Orifice, Balancing Valves:
  1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
     a. Armstrong Pumps, Inc.
     b. Bell & Gossett Domestic Pump; a division of ITT Industries.
     c. Griswold Controls.
     d. Taco.
  2. Body: Cast-iron or steel body, ball, plug, or globe pattern with calibrated orifice or venturi.
  3. Ball: Brass or stainless steel.
  4. Stem Seals: EPDM O-rings.
  5. Disc: Glass and carbon-filled PTFE.
  6. Seat: PTFE.
  7. End Connections: Flanged.
  8. Pressure Gage Connections: Integral seals for portable differential pressure meter.
  9. Handle Style: Lever, with memory stop to retain set position.
  10. CWP Rating: Minimum 125 psig.

E. Diaphragm-Operated, Pressure-Reducing Valves:
  1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
     a. Amtrol, Inc.
     b. Armstrong Pumps, Inc.
     c. Bell & Gossett Domestic Pump; a division of ITT Industries.
     d. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
  2. Body: Bronze or brass.
  3. Disc: Glass and carbon-filled PTFE.
  4. Seat: Brass.
  5. Stem Seals: EPDM O-rings.
  6. Diaphragm: EPT.
  7. Low inlet-pressure check valve.
  8. Inlet Strainer: Stainless steel, removable without system shutdown.
  9. Valve Seat and Stem: Noncorrosive.
  10. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

F. Diaphragm-Operated Safety Valves:
  1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
     a. Amtrol, Inc.
     b. Armstrong Pumps, Inc.
     c. Bell & Gossett Domestic Pump; a division of ITT Industries.

d. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. Body: Bronze or brass.
3. Disc: Glass and carbon-filled PTFE.
4. Seat: Brass.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Wetted, Internal Work Parts: Brass and rubber.
8. Inlet Strainer: Stainless steel, removable without system shutdown.
9. Valve Seat and Stem: Noncorrosive.
10. Valve Size, Capacity, and Operating Pressure: Comply with ASME Boiler and Pressure Vessel Code: Section IV, and selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

G. Automatic Flow-Control Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Griswold Controls.
   b. Macon
   c. Bell and Gossett
   d. Armstrong
2. Body: Brass or ferrous metal.
3. Piston and Spring Assembly: Stainless steel, tamper proof, self cleaning, and removable.
4. Pressure Gage Connections: Integral seals for portable differential pressure meter.
5. Identification Tag: Marked with valve number, and flow rate.
6. Size: Same as pipe in which installed.
7. Performance: Maintain constant flow, plus or minus 5 percent over an operating pressure differential range of at least 14 times the minimum required for control.
8. Minimum CWP Rating: 175 psig.
9. Maximum Operating Temperature: 250 deg F.

2.7 AIR CONTROL DEVICES

A. Manual Air Vents:

1. Body: Bronze.
2. Internal Parts: Nonferrous.
3. Operator: Screwdriver or thumbscrew.
4. Inlet Connection: NPS 1/2.
5. Discharge Connection: NPS 1/8.
6. CWP Rating: 150 psig.
7. Maximum Operating Temperature: 225 deg F.

B. Automatic Air Vent:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Armstrong Pumps, Inc.
      b. Bell & Gossett Domestic Pump; a division of ITT Industries.
      c. Hoffman.
      d. Spirax Sarco.
      e. Taco.
   2. Body: Bronze.
   3. Internal Parts: Nonferrous.
   4. Operation: Automatic float-principle.
   5. Inlet Connection: NPS 1/2
   6. Discharge Connection: NPS 1/4
   7. CWP Rating: 150 psig.
   8. Maximum Operating Temperature: 240 degrees F.

C. Bladder Expansion Tanks:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Armstrong Pumps, Inc.
      b. Bell & Gossett ITT; Div. of ITT Fluid Technology Corp.
      c. John Wood Company.
      d. Amtrol
   2. Tank: Welded carbon steel, rated for 125-psig working pressure and 240 degrees F maximum operating temperature, with taps in top of tank for system connection and tank charging, and tap in bottom of tank for draining. Tank shall be fitted with lifting rings. Provide a floor mounting skirt for vertical installations. Tanks shall be factory tested with taps fabricated and labeled according to the ASME Boiler and Pressure Vessel Code.
   3. Bladder: Replaceable heavy-duty, Butyl rubber.

D. Centrifugal Air Separator:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Armstrong Pumps, Inc.
      b. Bell & Gossett ITT; Div. of ITT Fluid Technology Corp.
      c. Spirax Sarco, Inc.
      d. Spirotherm, Inc.
   2. Separator: Cast-iron or steel body with tangential connections, perforated stainless steel air collector tube. Body diameter shall be not less than three times the nominal inlet/outlet pipe diameter with a body volume for sufficient velocity reduction. Maximum working pressure of 125 psig and temperature of 250 degrees F. Air separator shall be fabricated and labeled according to ASME Boiler and Pressure Vessel Code Section VIII, Division I.

E. In-Line Air Separators:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
a. Amtrol, Inc.
b. Armstrong Pumps, Inc.
c. Bell & Gossett Domestic Pump; a division of ITT Industries.
d. Taco.
2. Tank: One-piece cast iron with an integral weir constructed to decelerate system flow to maximize air separation.
3. Maximum Working Pressure: Up to 175 psig.
4. Maximum Operating Temperature: Up to 300 deg F.

2.8 HYDRONIC PIPING SPECIALTIES

A. Bypass Chemical Feeder: Welded steel construction; 125-psig working pressure; 5-gal. capacity; with fill funnel and inlet, outlet, and drain valves

B. Y-Pattern Strainers.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
a. Armstrong Pumps, Inc.
b. Bell & Gossett ITT; Div. of ITT Fluid Technology Corp.
c. Griswold Controls.
d. Mueller Steam Specialty.
e. Spirax Sarco Inc.
2. Body: ASTM A 126, Class B, cast iron, or ASTM A 395, Grade 64-45-15 or ASTM A536, Grade 64-45-12 ductile iron, with bolted cover and bottom drain connection for NPS 2-1/2 and larger. Bronze body with threaded cover and bottom drain connection for NPS 2 and smaller.
3. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.
4. Strainer Screen: 40-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
5. CWP Rating: 125 psig.

C. Stainless-Steel Bellow, Flexible Connectors:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
a. Flex-Hose Co., Inc.
b. Flexonics.
c. Metraflex.
d. Twin City Hose.
2. Body: Stainless-steel bellows with woven, flexible, stainless steel, wire-reinforcing protective jacket.
3. End Connections: Threaded or flanged to match equipment connected.

4. Performance: Capable of 3/4-inch misalignment.
5. CWP Rating: 150 psig.

D. Flexible Pump Connectors:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Mason Industries.
   b. Metraflex Co.
   c. Proco Products, Inc.
   d. Vibration Mountings & Controls, Inc.
2. Body: Flexible, single- or double-sphere of EPDM liner and cover, Kevlar tire cord fractioning with steel ring embedded in raised face of rubber-flanged end. Provide ductile iron, external ring between double-spheres.
3. End Connections: Split ductile-iron or steel flanges with hooked interlocks.
4. Control Rods: Required where recommended by manufacturer or indicated on Drawings.
5. CWP Rating: 150 psig.
6. Maximum Operating Temperature: 250 degrees F

2.9 DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

2.10 BYPASS CHEMICAL FEEDER

A. Description: Welded steel construction; 125-psig working pressure; 5-gal. capacity; with fill funnel and inlet, outlet, and drain valves.

B. Chemicals: Specially formulated, based on analysis of makeup water, to prevent accumulation of scale and corrosion in piping and connected equipment.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Chilled-water piping, aboveground, NPS 2 and smaller, shall be any of the following:
1. Type K, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.
2. Schedule 40 steel pipe; Class 125, cast-iron or Class 150, malleable-iron fittings; cast-iron flanges and flange fittings; and threaded joints. Mechanically grooved fittings and couplings are not acceptable except within service clearance of equipment.

B. Chilled-water piping, aboveground, NPS 2-1/2 and larger, shall be any of the following:
   1. Type K, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.
   2. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints. Mechanically grooved fittings and couplings are not acceptable except within service clearance space of equipment and NPS 4 and smaller.

C. Condenser water piping, aboveground, NPS 2 and smaller, shall be any of the following:
   1. Type K, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.
   2. Schedule 40 steel pipe; Class 125, cast-iron or Class 150, malleable-iron fittings; cast- iron flanges and flange fittings; and threaded joints.
   3. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints within service clearance space of equipment.

D. Condenser water piping, aboveground, NPS 2-1/2 and larger, shall be any of the following:
   1. Type K, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.
   2. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
   3. Schedule 40 steel pipe; grooved, mechanical joint coupling and fittings; and grooved, mechanical joints within service clearance of equipment and NPS 4 and smaller.
   4. Steel pipe and fittings installed outside shall be galvanized.

E. Condenser Water Piping below ground and within slabs, NPS 2 and smaller shall be any of the following:
   1. Type K, annealed-temper copper tubing, wrought-copper fittings, and brazed joints. Use fewest joints possible. All underground copper tube shall be protected with 20 mil plastic sleeve.
   2. Schedule 40 steel pipe; and welded joints.
   3. Steel pipe and fittings installed belowground shall have protective coating as specified in “Protective Coating” Article in Part 2.

F. Condenser Water Piping below ground and within slabs, NPS 2 1/2 and larger shall be any of the following:
   1. Type K, annealed-temper copper tubing, wrought-copper fittings, and brazed joints. Use fewest joints possible. All underground copper tube shall be protected with 20 mil plastic sleeve.
   2. Schedule 40 steel pipe; welded joints.
   3. Steel pipe and fittings installed belowground shall have protective coating as specified in “Protective Coating” Article in Part 2.

G. Makeup-water piping shall be the following:
   1. Makeup-water piping installed aboveground: Type K, drawn-temper copper tubing, wrought-copper fittings, and soldered or brazed joints.
   2. Makeup-Water Piping Installed Belowground and within Slabs: Type K, annealed-temper copper tubing, wrought-copper fittings, and brazed joints. Use the fewest possible joints. All underground copper tube shall be protected with 20 mil plastic sleeve.

H. Blowdown-Drain Piping: Same materials and joining methods as for piping specified for the service in which blowdown drain is installed.

I. Air-Vent Piping:
   1. Inlet: Same as service where installed.
   2. Outlet: Type K, annealed-temper copper tubing with soldered or flared joints.

J. Safety-Valve-Inlet and -Outlet Piping for Hot-Water Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed.

3.2 VALVE APPLICATIONS

A. Install shutoff-duty valves at each branch connection to supply and return mains, and at supply connection to each piece of equipment.

B. Install calibrated balancing valves in the return pipe of each heating or cooling terminal and elsewhere as required to facilitate system balancing.

C. Install check valves at each pump discharge and elsewhere as required to control flow direction.

D. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install safety-valve discharge pipe without valves to nearest floor sink or floor drain, or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code for installation requirements.

E. Install pressure-reducing valves at makeup- and fill-water connection to regulate system pressure.

3.3 PIPING INSTALLATIONS

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

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

C. Install piping 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 servicing of valves and specialties.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

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

I. Install piping to allow application of insulation.

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

K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.

L. Install drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.

N. Reduce pipe sizes using concentric reducer fittings. Exception: Use eccentric reducer fitting installed with level side up on condenser water pump suction piping.

O. Make branch connections to mains using flow tees where branch size is not less than 1/3 the diameter of the main. Weld-O-Lets and Thread-O-Lets, may be used in other applications. Hot-taps shall only be used to connect branch lines to live mains.

P. Unless otherwise indicated, install branch connections to mains with the branch connected to the top or side of the main pipe.

Q. Install valves according to Division 23 Section 23 05 23 "General-Duty Valves for HVAC Piping."

R. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

S. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.

T. Install grooved steel mechanical fittings within service clearance space of equipment and NPS 4 and smaller where indicated.

U. Install strainers on inlet side of each control valve, pressure-reducing valve, solenoid valve, in-line pump, and elsewhere as indicated. Install NPS 3/4 nipple and ball valve in blowdown connection of strainers NPS 2 and larger. Match size of strainer blowoff connection for strainers smaller than NPS 2. Select mesh opening size based on item being protected.

V. Provide concrete thrust blocks at all changes in direction, dead ends, reducers and valves in underground piping.

W. Identify piping as specified in Division 23 Section 23 05 53 "Identification for HVAC Piping and Equipment."

3.4 HANGERS AND SUPPORTS

A. Hanger, support, and anchor devices are specified in Division 23 Section 23 05 29 "Hangers and Supports for HVAC Piping and Equipment." Comply with the following requirements for maximum spacing of supports.

B. Install the following pipe attachments:

1. Adjustable steel clevis hangers for individual runs of horizontal piping less than 20 feet long.
2. Adjustable roller hangers and spring hangers for individual runs of horizontal piping 20 feet or longer.
3. Pipe Roller: MSS SP-58, Type 44 for multiple adjacent runs of horizontal piping 20 feet or longer, supported on a trapeze.
4. Spring hangers to support horizontal piping adjacent to the top and bottom of vertical runs.
5. Provide spring hangers on the first three hangers adjacent to spring-isolated, rotating equipment.

C. Install hangers for individual runs steel piping with the following maximum spacing and minimum rod sizes:

1. NPS 3/4: Maximum span, 7 feet; minimum rod size, 1/4 inch.
2. NPS 1: Maximum span, 7 feet; minimum rod size, 1/4 inch.
3. NPS 1-1/2: Maximum span, 9 feet; minimum rod size, 3/8 inch.
4. NPS 2: Maximum span, 10 feet; minimum rod size, 3/8 inch.
5. NPS 2-1/2: Maximum span, 11 feet; minimum rod size, 3/8 inch.
6. NPS 3: Maximum span, 12 feet; minimum rod size, 3/8 inch.
7. NPS 4: Maximum span, 14 feet; minimum rod size, 1/2 inch.
8. NPS 6: Maximum span, 17 feet; minimum rod size, 1/2 inch.
9. NPS 8: Maximum span, 19 feet; minimum rod size 5/8 inch.
10. NPS 10: Maximum span, 20 feet; minimum rod size, 3/4 inch.
11. NPS 12: Maximum span, 23 feet; minimum rod size, 7/8 inch.
12. NPS 14 thru 16: Maximum span, 25 feet; minimum rod size, 1 inch.
13. NPS 18 thru 20: Maximum span, 28 feet; minimum rod size, 1-1/4 inch.

D. Install hangers for individual runs of drawn-temper copper piping with the following maximum spacing and minimum rod sizes:
   1. NPS 3/4: Maximum span, 5 feet; minimum rod size, 1/4 inch.
   2. NPS 1: Maximum span, 6 feet; minimum rod size, 1/4 inch.
   3. NPS 1-1/2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
   4. NPS 2: Maximum span, 8 feet; minimum rod size, 3/8 inch.
   5. NPS 2-1/2: Maximum span, 9 feet; minimum rod size, 3/8 inch.
   6. NPS 3: Maximum span, 10 feet; minimum rod size, 3/8 inch.
   7. NPS 4: Maximum span, 12 feet; minimum rod size, 1/2 inch.
   8. NPS 6: Maximum span, 14 feet; minimum rod size, 1/2 inch.

E. Support vertical runs at roof, at each floor, and at 10-foot intervals between floors.

3.5 PIPE JOINT CONSTRUCTION

A. Join pipe and fittings according to the following requirements and Division 23 Sections specifying piping systems.

B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

D. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.

E. 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.

F. 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.

G. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

H. Grooved Steel Joints: Assemble joints with coupling and gasket, lubricant, and bolts. Cut or roll grooves in ends of pipe based on pipe and coupling manufacturer's written instructions for pipe wall thickness.

3.6 PROTECTIVE COATING

A. Field Applied Tape. Apply to all joints, fittings and other areas where the factory applied coating is missing or damaged.
   1. Apply to clean and dry surfaces.
   2. Apply adhesive primer prior to application of tape.
   3. Wrap tape with minimum 50 percent overlap.
   4. Extend tape a minimum of 4 inches over intact, factory-applied coating.

3.7 HYDRONIC SPECIALTIES INSTALLATION

A. Install manual air vents at high points in piping, at heat-transfer coils, and elsewhere as required for system air venting.

B. Install automatic air vents in mechanical equipment rooms at high points of system piping, at heat transfer coils, at the air outlet on the air separator, and elsewhere as required for system air venting.
   1. Provide shutoff valve on inlet side of each automatic air vent.
   2. Provide drain piping from each automatic air vent outlet to nearest floor sink, mop sink or floor drain.

C. Install piping from boiler air outlet, air separator, or air purger to expansion tank with a 2 percent upward slope toward air vent.

D. Install in-line air separators in pump suction NPS 1-1/2 and smaller and centrifugal air separators in NPS 2 through NPS 24. Install drain valve on air separators NPS 2 and larger.

E. Install bypass chemical feeders in each hydronic system where indicated, in upright position with top of funnel not more than 48 inches above the floor. Install feeder where indicated on Drawings, using full port ball valve on inlet and outlet. Install NPS 3/4 pipe from chemical feeder drain, to nearest equipment drain and include a full-size, full-port, ball valve.

F. Install expansion tanks where indicated on Drawings.
   1. Charge tank to initial fill pressure.
   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.

3.8 TERMINAL EQUIPMENT CONNECTIONS

A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.

B. Install control valves in accessible locations close to connected equipment.

C. Install ports for pressure gages and thermometers at coil inlet and outlet connections according to Division 23 Section 23 05 19 "Meters and Gages for HVAC Piping."

D. Install flexible connectors at the inlet and outlet of all moving equipment, except pumps. Match size of adjacent pipe.

E. Install flexible pump connectors at the inlet and outlet of all pumps, except in-line pumps. Match size of adjacent pipe.

3.9 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:
   1. Leave joints, including welds, uninsulated and exposed for examination during test.
   2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
   3. 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.
   4. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:
   1. Use ambient temperature water as a testing medium. Air pressure testing is not acceptable.
   2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
   3. Isolate expansion tanks and determine that hydronic system is full of water.
   4. Subject piping system to hydrostatic test at a pressure of 50 psi above working pressure designated by the Engineer of Record. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
   5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks. Test for four hours minimum.
   6. Prepare written report of testing.

C. Perform the following before operating the system:
   1. Open manual valves fully. Close bypass valves
   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 correctly (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Verify lubrication of motors and bearings

3.10 CLEANING

A. Fill the hydronic piping system with clean water and using chemicals supplied by the HVAC Water Treatment Contractor circulate at a rate of no less than 1/2 design flow. Circulate chemicals as directed (not less than 72 hours) to remove oils, dirt, and other compounds detrimental to the proper operation of the system. Remove and clean the strainer screens.

B. Flush the hydronic piping systems with clean water (“bleed and feed”). Samples are to be taken by the HVAC Water Treatment Contractor and tested at a 3rd party laboratory until the water quality reaches the prescribed requirements. Remove and clean strainer screens.

C. After cleaning and flushing hydronic piping systems, but before balancing, remove disposable fine-mesh start-up strainers in pump suction diffusers and replace with permanent strainer. Assist the HVAC Water Treatment Contractor as required to introduce the regular treatment chemicals into the hydronic piping system.

3.11 ACCEPTANCE

A. Coordinate opening of new piping to existing system with owner. Only after a successful pressure test and the Plant operator/Owner personnel have approved and accepted the test results will the system valves connecting the building to the central utility be unlocked and opened (by Owner).

END OF SECTION

SECTION 23 21 14

PRE-INSULATED PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Steel pipes and fittings.
   2. Transition fittings.
   3. Cased piping system.

B. Related Requirements:
   1. Section 23 21 13 “Hydronic Piping”

1.2 ACTION SUBMITTALS

A. Product Data: Indicate material data, a list of materials, thickness of material, installation instructions, etc. for each type of pipe, fitting, and joint for each piping system proposed.

B. Shop Drawings: Factory-certified dimensioned installation shop drawings for all underground chilled water supply and return piping including installation details, expansion compensation, supports, backfill and compaction recommendations, etc.

1.3 INFORMATIONAL SUBMITTALS

A. Profile Drawings: Show system piping in elevation. Draw profiles at horizontal scale of not less than 1 inch equals 50 feet and at vertical scale of not less than 1 inch equals 5 feet. Indicate manholes and piping. Show types, sizes, materials, and elevations of other utilities crossing hydronic piping.

B. Qualification Data: For qualified Installer.

C. Welding certificates.

D. Material Test Reports: For preinsulated piping.

E. Source quality-control reports.

F. Field quality-control reports.
   1. Certified manufacturer’s representative shall visit the site during installation and submit documentation that carrier pipe and fittings are installed per manufacturer’s written directions.

1.4 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX.
   1. Comply with provisions in ASME B31.9, "Building Services Piping."
   2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

B. ASME Compliance: Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.

1.5 JOB CONDITIONS

A. All underground utilities except copper pipe, shall have a separate copper tracer wire and non-metallic warning tape installed above the utility line. The tracer wire shall be traced for continuity prior to backfill, immediately upon completion of backfill and compaction and once again during final utility location/as-built at the end of the Project. This also will include landscape irrigation mains to the points of the valves.

B. Where connecting to existing chilled water lines and/or valves, the contractor must do a field verification of supply or return. Do not depend on as-built information, Owner personnel, or existing designations that may be found.

C. Deliver to job site in original unbroken factory packaging, labeled with manufacturer's density and thickness.

D. Perform work at ambient and equipment temperatures as recommended by adhesive manufacturer.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Where possible, store materials inside and protected from weather. Where outside storage is necessary, elevate above grade and enclose with durable, waterproof wrapping.

B. Protect flanges and fittings from moisture and dirt by inside storage and enclosure or by packaging with durable, waterproof wrapping.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

A. Acceptable Manufacturers:
   1. ETF West
   2. Rovanco
   3. Ricwil

4. Thermal Pipe System
5. Thermacorp

2.2 GENERAL

A. Adhesives, jacketing and insulating materials shall have composite fire and smoke hazard ratings maximum 25 for Flame Spread and 50 for Smoke Developed. Adhesive and jacketing shall be waterproof.

B. Manufacturer shall provide drawings stamped by a Professional Engineer indicating any locations where “Z Bends” or anchoring provisions are required.

2.3 MATERIALS AND COMPONENTS

A. Insulation: Polyurethane foam closed cell pipe insulation. With K-Factor of 0.13 and density of 2 pcf conforming with ASTM C-591. Insulation shall be factory applied and shall completely fill the annular space between the carrier pipe and jacketing. Minimum insulation thickness to be 1.5 inches.

B. Carrier pipe: Welded or flanged Schedule 40 black steel or Type L copper. See Section 23 21 13 “Hydronic Piping.”

C. Jacketing: High impact, seamless PVC Class 12454-B compound conforming to ASTM 1784. The following casing sizes and thicknesses shall be used for all site conditions:

Carrier Size	Casing Size	Minimum Casing Thickness
4”	8”	.125”
6”	10”	.125”
8”	12”	.125”
10”	14”	.125”
12”	16”	.125”

D. Jacketing for carrier pipe 14” and larger shall be HDPE material with minimum thickness of 180 mil for 14” carrier pipe.

E. Fittings: Cover fittings and valves with equivalent thickness and material if field insulated and jacketed using manufacturers standard fitting insulation kit.

F. End Seals: End seals for pre-insulated pipe shall be designed to resist infiltration of water at the intended operating temperature. Mastic end seals shall not be allowed.

G. Straight Joints: Solid PVC sleeve to overlap jacketing on both sides of joint. Sleeve to be sealed to jacket with manufacturers specific tape. A hole shall be drilled in the sleeve and the annular space shall be filled with Polyurethane foam. Hole is then to be plugged and sealed.

H. Sleeves: Provide concrete slab or wall penetration sleeves where piping passes through masonry or concrete walls or slabs. Sleeves in outside walls or slabs below and above grade shall be schedule 40 or standard weight coated black steel pipe.

1. Sleeves shall be held securely in proper position and location during construction.
2. Sleeves shall be of sufficient length to pass through entire thickness of walls or slabs. Refer to details on drawings.
3. In existing concrete slabs or walls, penetrations may be made using the "core drilling" method, providing proper care is taken to drill the holes to the size needed and square to the line of the pipe.

I. Wall and Slab Penetration Seals: All wall and slab penetrations shall be sealed to prevent water from entering the building or below slab.

J. Mechanical Sleeve Seals: At seals into building, provide modular mechanical type, consisting of interlocking synthetic rubber links shaped to continuously fill annular space between pipe and sleeve, connected with bolts and pressure plates which cause rubber sealing elements to expand when tightened, providing watertight seal and electrical insulation.

1. Manufacturer: Subject to compliance with requirements, provide mechanical sleeve seals of the following:
   a. Thunderline Corp.
   b. Proset
   c. GPT Industries

PART 3 - EXECUTION

3.1 GENERAL

A. Installation of the piping system shall be done in accordance with the appropriate publications including ANSI B31.1 and the following specifications and instructions. A manufacturer's field representative shall conduct an installation clinic to pre-qualify contract personnel in the proper procedures for the installation.

B. Pipe shall be accurately cut to dimensions established at the construction site and worked into place without springing or forcing, properly clearing all openings and equipment. Excessive cutting or other weakening of structural members to facilitate piping installation shall not be permitted. Pipe ends shall have burrs removed by reaming and shall be installed to permit free expansion and contraction without damage to joints. Good workmanlike procedures shall be followed. Ensure surface is clean and dry prior to installation. Ensure insulation is dry before and during application. Finish with systems at operating conditions.

C. Follow manufacturer direction in regard to inspection, unloading, storage and transfer of pipe at the site.

D. Do not install covering before piping and equipment has been tested and approved.

E. Ensure surface is clean and dry prior to installation. Ensure insulation is dry before and during application. Finish with systems at operating conditions.

3.2 EXCAVATION

A. The trench bottom shall give uniform support along the entire length of any pipelines. Where several pipelines are located in a common trench, the trench shall be wide enough to maintain the specified distances between adjacent lines, a minimum of 6" in pipe sizes up 6" diameter and 12" minimum in sizes 8" and larger. The excavation shall be in a straight line, except where fittings are located.

3.3 TRENCHING

A. The trench depth shall allow for a minimum cover height of 30" over the top of the casing pipe. Keep excavations free of water during construction. If it is necessary to remove unsuitable material to a depth greater than specified, refill over excavated area to the proper depth with specified bedding material and compact in 6" lifts to 95% of maximum density in accordance with ASTM D1557, Method D. Excavate and replace soil disturbed and weakened by the Contractor's operations or soils permitted to soften from exposure to weather with bedding material and compact it with a plate-type vibratory compactor.

B. The width of the trench at the top of the pipe shall be held to the minimum required for efficient and proper installation. The minimum recommended trench width at the top of the pipe shall be one foot greater than the outside diameter of the casing. Where two or more pipes are in the same trench, use the distance between outside casing of the outside pipes plus one foot. To determine the maximum trench width, use above method for minimum plus two feet.

3.4 DISTRIBUTING PIPE ALONG TRENCH

A. Pipe lengths may be strung along the line of the trench so as to minimize additional handling during installation. Do not remove protective materials from the pipe ends until the pipe is lowered into the trench and ready for connection of the next section of pipe. Open ends of pipe shall be completely clean of sand, dirt and debris before the next section of pipe is installed.

3.5 PLACING PIPE IN THE TRENCH

A. The pipe may be passed into the trench by hand or mechanically. The latest state and federal safety regulations shall be understood and observed. If slings are necessary, use only canvas straps. Do not use cable or chain slings.

3.6 BEDDING

A. Bedding material shall be sand, pea gravel, or other materials free of sharp objects, heavy clods, boulders, rocks, etc. The approved bedding shall be used 6" under, around and over the pipe. Utilize the best professional practices that apply to buried pressure piping.

B. Provide tracer wire 12” above piping extending full length of piping. Confirm continuity of wire after backfill is complete and at completion of the project. Provide letter to owner certifying continuity has been tested with date of testing.

3.7 ASSEMBLY OF PIPE AND FITTINGS

A. Pipe and fittings shall be assembled in strict accordance with the manufacturer's printed directions by personnel who have been instructed in installation procedures by the manufacturer's representative.

B. A field representative of the carrier pipe manufacturer shall conduct a construction seminar at the site to instruct Contractor's personnel in the proper methods and procedures for making field joints. Certification of instruction and competence shall be issued to those personnel so trained and only those so certified shall be permitted to perform work on the pipe. Owner’s personnel may wish to attend seminar. Notify Owner of time and location one week prior to seminar.

3.8 TESTING

A. After piping is installed, a hydrostatic test shall be applied. A test pressure of 50 psi above working pressure for four hours shall be conducted for the entire system. Joints should be visually inspected and proved tight. All pressure testing shall be witnessed by the Owner with documentation presented by the Contractor and signed off by the Owner.

B. During pressure testing and operational test, examine system for leaks. Repair leaks, replace damaged or porous pipe and fittings, and repeat all tests until satisfactory tests are achieved. (Test shall be inspected by the Owner or Owner’s agent)

3.9 BACKFILLING

A. Backfilling of trenches shall progress as rapidly as construction, testing, and acceptance of work permits. Uniformly compact and grade bottom of trenches. After installation of pipe and bedding material, backfill as follows. Place initial backfill in layers to a depth of 12" of the initial bedding. Compact the material to a density equivalent to the surrounding undisturbed soil or to 90% of maximum density (ASTM D1557, Method D), whichever is greater. Backfill remainder of trench in one-foot lifts and compact to 90% maximum density (ASTM D1557, Method D). For trenches excavated in roads, streets, or located under structures, place backfill in 6" layers to top of trench and compact each layer to at least 95% maximum density (ASTM D1557, Method D).

B. Notify Owner between each lift so that the testing agency may conduct compaction testing prior to commencing with additional backfill.

3.10 FIELD CUTTING PIPE TO A SPECIFIC LENGTH

A. Field cutting of pipe shall be performed in strict accordance with the manufacturer's printed directions by personnel who have been instructed in installation procedures by the manufacturer's representative.

3.11 FIELD QUALITY CONTROL

A. Prepare hydronic piping according to ASME B31.9 and as follows:
   1. Leave joints, including welds, uninsulated and exposed for examination during test.
   2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
   3. 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.
   4. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.

B. Perform the following tests on hydronic piping:
   1. Use ambient temperature water as a testing medium. Air pressure testing is not acceptable.
   2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.
   3. Isolate expansion tanks and determine that hydronic system is full of water.
   4. Subject piping system to hydrostatic test at a pressure of 50 psi above working pressure designated by the Engineer of Record. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
   5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks. Test for four hours minimum.
   6. Prepare written report of testing.

C. Perform the following before operating the system:
   1. Open manual valves fully. Close bypass valves
   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 correctly (automatic type), or bleed air completely (manual type).
5. Set temperature controls so all coils are calling for full flow.
6. Verify lubrication of motors and bearings

3.12 CLEANING

A. Fill the hydronic piping system with clean water and using chemicals supplied by the HVAC Water Treatment Contractor circulate at a rate of no less than 1/2 design flow. Circulate chemicals as directed (not less than 72 hours) to remove oils, dirt, and other compounds detrimental to the proper operation of the system. Remove and clean the strainer screens.

B. Flush the hydronic piping systems with clean water ("bleed and feed"). Samples are to be taken by the HVAC Water Treatment Contractor and tested at a 3rd party laboratory until the water quality reaches the prescribed requirements. Remove and clean strainer screens.

C. After cleaning and flushing hydronic piping systems, but before balancing, remove disposable fine-mesh start-up strainers in pump suction diffusers and replace with permanent strainer. Assist the HVAC Water Treatment Contractor as required to introduce the regular treatment chemicals into the hydronic piping system.

D. Piping manufacturer's Written Certification: After testing and prior to start-up of the system, the manufacturer must certify in writing that the system was installed per the manufacturer's installation instructions and that piping jacketing is properly sealed at all joints.

3.13 ACCEPTANCE

A. Coordinate opening of new piping to existing system with owner. Only after a successful pressure test and the Plant operator/Owner personnel have approved and accepted the test results will the system valves connecting the building to the central utility be unlocked and opened (by Owner personnel).

END OF SECTION

SECTION 23 21 23

HYDRONIC PUMPS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. In-Line Circulators
   2. Compact In-Line Circulators
   3. In-Line Pumps
   4. Base Mounted Close-coupled, end-suction pumps.
   5. Base Mounted Flex-coupled, end-suction pumps.
   6. Base Mounted Flex-coupled Horizontal Split Case pumps.
   7. Pump accessories.

1.2 ACTION SUBMITTALS

A. Product Data: Include pump dimensions, weights, certified performance curves and rated capacities; furnished specialties; final impeller dimensions; motor data, and accessories for each pump indicated. Indicate pump's operating point on curves.

1.3 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.4 QUALITY ASSURANCE

A. UL Compliance: Fabricate and label pumps to comply with UL 778, "Motor-Operated Water Pumps," for construction requirements.

B. Regulatory Requirements: Fabricate and test steam condensate pumps to comply with the Hydraulic Institute (HI) standards including HI 1.1-1.5, “Centrifugal Pumps for Nomenclature, Definitions, Application and Operation,” and HI 1.6, “Centrifugal Pump Tests.”

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

2.2 GENERAL PUMP REQUIREMENTS

A. Pump Units: Factory assembled and tested.

B. Motors: Include built-in, thermal-overload protection on single phase motors and grease-lubricated ball bearings on motors. Select each motor to be no overloading over full range of pump performance curve. See Division 23 Section 23 05 13 "Common Motor Requirements for HVAC Equipment" for general motor requirements.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

D. Default motor characteristics are specified in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."

E. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."

2.3 IN-LINE CIRCULATORS

A. Factory assembled and tested horizontal, in-line, centrifugal, single-stage, radially split case design; rated for 125-psig minimum working pressure and a continuous water temperature of 225 degrees F, designed for installation with pump and motor shafts mounted horizontally or vertically.

1. Manufacturers
   - Armstrong Pumps Inc.
   - Bell & Gossett ITT; Div. of ITT Fluid Technology Corp.
   - Grundfos Pumps Corp.
   - Taco; Fabricated Products Div.

B. Casing: Bronze, with threaded companion flanges or unions for piping connections, and threaded gage tapings at inlet and outlet connections.

C. Impeller: ASTM B 36/B 36M, rolled-temper-brass fabrication, statically and dynamically balanced, closed, overhung, single suction, and keyed to shaft.

D. Shaft and Sleeve: Stainless Steel shaft with oil-lubricated copper sleeve.

E. Seals: Mechanical type, carbon-steel rotating ring, stainless-steel spring, ceramic seat, and flexible bellows and gasket.

F. Pump Bearings: Oil-lubricated, bronze journal and thrust type.

G. Motor Bearings: Oil-lubricated, sleeve type, or permanently lubricated ball bearings.

H. Coupling: Flexible, capable of absorbing torsional vibration and shaft misalignment.

I. Motor: Resiliently mounted to pump casing.

2.4 COMPACT IN LINE CIRCULATORS

A. Cartridge type, horizontal, in-line, compact, seal-less, centrifugal, and single stage. Include pump and motor assembled on a common shaft in cartridge-type, hermetically sealed unit, without stuffing boxes or mechanical seals. Include isolation of motor section from motor-stator windings by corrosion-resistant, nonmagnetic, alloy liner. Include design rated for 125-psig minimum working pressure and a continuous water temperature of 225 degrees F.
   1. Manufacturers:
      a. Armstrong Pumps, Inc.
      b. Bell & Gossett ITT; Div. of ITT Fluid Technology Corp.
      c. Grundfos Pumps Corp.
      d. Taco; Fabricated Products Div.
   2. Casing: Lead-free cast bronze, with stainless-steel liner, static O-ring seal to separate motor section from motor stator, and flanged piping connections.
   3. Impeller: Overhung, single suction, closed or open, nonmetallic.
   4. Shaft and Sleeve: Stainless-steel shaft with carbon-steel sleeve.
   5. Motor: Single speed.

2.5 IN LINE PUMPS

A. Factory assembled and tested horizontal, flexible-coupled or close-coupled, in-line, centrifugal, single-stage, radially split case design; designed for installation with pump and motor shafts mounted horizontally or vertically as indicated on Drawings. Pump shall be bronze-fitted design with mechanical seals rated for 175-psig minimum working pressure and a continuous water temperature of 225 degrees F.
   1. Manufacturers:
      a. Armstrong Pumps, Inc.
      b. Bell & Gossett ITT; Div. of ITT Fluid Technology Corp.
      c. Goulds Pumps, Inc.
      d. Grundfos Pumps Corp.
      e. Taco; Fabricated Products Div.
   2. Casing: Cast iron, with threaded companion flanges for piping connections NPS 2 inches and smaller, and Class 125 flanges NPS 2-1/2 inches and larger, drain plug at low point of volute, and threaded gage tappings at inlet and outlet connections.

3. Impeller: ASTM B 584, cast bronze, statically and dynamically balanced, closed, overhung, single suction, and keyed to shaft.
4. Shaft and Sleeve: Ground and polished stainless-steel shaft with bronze sleeve.
5. Seals: Mechanical, with carbon-steel rotating ring, stainless-steel spring, ceramic seat, and flexible bellows and gasket.
6. Motor: Directly mounted to pump casing. Vertical pumps shall have lifting and supporting lugs in top of motor enclosure.

2.6 CLOSE-COUPLED, END-SUCTION PUMPS

A. Factory assembled and tested, centrifugal, close-coupled, end-suction, single-stage, bronze-fitted, back-pull-out, radially split case design; rated for 175-psig minimum working pressure and a continuous water temperature of 225 degrees F.
   1. Manufacturers:
      a. Armstrong Pumps, Inc.
      b. Bell & Gossett ITT; Div. of ITT Fluid Technology Corp.
      c. Goulds Pumps, Inc.
      d. Taco; Fabricated Products Div.
   2. Casing: Cast iron, with threaded or flanged piping connections, drain plug at low point of volute, air vent at top, and threaded gage tappings at inlet and outlet connections.
   3. Impeller: ASTM B 584, cast bronze, statically and dynamically balanced, closed, overhung, single suction, keyed to shaft, and secured by locking cap screw.
   4. Shaft: Stainless-steel shaft, or carbon steel shaft with copper alloy shaft sleeve, close coupled to motor shaft.
   5. Seals: Mechanical, with carbon-steel rotating ring, stainless-steel spring, ceramic seat, and flexible bellows and gasket.
   6. Motor: Directly mounted to pump casing and with supporting legs as integral part of motor enclosure.

2.7 BASE MOUNTED, FLEXIBLE-COUPLED, END SUCTION PUMPS

A. Factory assembled and tested centrifugal, base-mounted, flexible-coupled, end-suction, single-stage, bronze-fitted, back-pull-out, radially split case design; rated for 175-psig minimum working pressure and a continuous water temperature of 225 degrees F.
   1. Manufacturers
      a. Armstrong Pumps, Inc.
      b. Bell & Gossett ITT; Div. of ITT Fluid Technology Corp.
      c. Goulds Pumps, Inc.
      d. Taco; Fabricated Products Div.
   2. Casing: Cast iron, with threaded or flanged piping connections, drain plug at low point of volute, air vent at top and threaded gage tappings at inlet and outlet connections.

3. Impeller: ASTM B 584, cast bronze or stainless steel, statically and dynamically balanced, closed, overhung, single suction, keyed to shaft, and secured by locking cap screw.
4. Shaft: Stainless-steel shaft, or carbon steel shaft with copper alloy shaft sleeve, with 2, heavy-duty bearing assemblies. Provide flexible coupling and guard for connection to motor shaft.
5. Seals: Mechanical, with carbon-steel rotating ring, stainless-steel spring, ceramic seat, and flexible bellows and gasket.
6. Motor: Directly mounted to pump casing and with supporting legs as integral part of motor enclosure.
7. Base: Structural steel or fabricated steel channels with fully enclosed sides and ends with welded steel cross members. The base shall have a top opening for grouting.

2.8 BASE-MOUNTED, FLEXIBLE-COUPLED, HORIZONTAL SPLIT CASE PUMPS

A. Factory assembled and tested centrifugal, base-mounted, flexible-coupled, horizontal split case, single-stage, bronze-fitted design; rated for 175-psig minimum working pressure and a continuous water temperature of 225 degrees F.
   1. Manufacturers:
      a. Armstrong Pumps, Inc.
      b. Bell & Gossett ITT; Div. of ITT Fluid Technology Corp.
      c. Goulds Pumps, Inc.
      d. Taco; Fabricated Products Div.
   2. Casing: Cast iron, with flanged piping connections, drain plug at low point of volute, air vent at top, and threaded gage tappings at inlet and outlet connections.
   3. Impeller: ASTM B 584, cast bronze or stainless steel, statically and dynamically balanced, keyed to shaft, and secured by locking cap screw.
   4. Shaft: Stainless-steel shaft, or carbon steel shaft with copper alloy shaft sleeve, with 2, heavy-duty bearing assemblies. Provide flexible coupling and guard for connection to motor shaft.
   5. Seals: Mechanical, with carbon-steel rotating ring, stainless-steel spring, ceramic seat, and flexible bellows and gasket.
   6. Motor: Directly mounted to pump casing and with supporting legs as integral part of motor enclosure.
   7. Base: Structural steel or fabricated steel channels with fully enclosed sides and ends with welded steel cross members. The base shall have a top opening for grouting.
   8. Provide with jacking screws for alignment.

2.9 AUTOMATIC CONDENSATE PUMP UNITS

A. Packaged units with corrosion-resistant pump, plastic tank with cover, and automatic controls including a level safety capable of equipment shutoff and alarm output. Include factory- or field-installed check valve and a 72-inch- minimum, electrical power cord with plug.

1. Manufacturers:
   a. Beckett Corp.
   b. Hartell Div.; Milton Roy Co.
   c. Little Giant Pump Co.

2.10 PUMP SPECIALTY FITTINGS

A. Suction Diffuser: Angle pattern, 175-psig pressure rating, cast-iron body and end cap, pump-inlet fitting; with bronze startup and bronze or stainless-steel permanent strainers; bronze or stainless-steel straightening vanes; magnetic drain plug; and adjustable support foot.

PART 3 - EXECUTION

3.1 PUMP INSTALLATION

A. Install pumps to provide access for periodic maintenance, including removing motors, impellers, couplings, and accessories.

B. Completely fill base of base-mounted pumps with non-shrinking grout.

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 on cast-in-place isolated concrete equipment bases. Provide inertia bases where indicated.
2. Install in-line pumps with continuous-thread hanger rods and spring hangers of size required to support weight of in-line pumps.

3.2 CONNECTIONS

A. Install piping adjacent to machine to allow service and maintenance.

B. Connect piping to pumps. Install valves that are the 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 valve and throttling valve on discharge side of in-line circulators.

E. Install wye strainer and shutoff valve on suction side of in-line pumps.

1. Install blowdown piping with ball valve at each wye strainer or suction diffuser. Extend piping to nearest drain.

F. Install non-slam check valve and shutoff valve, on discharge side of in-line, close-coupled and base-mounted pumps, as applicable.

G. Install suction diffuser, or wye strainer, and shutoff valve on suction side of close-coupled and base-mounted pumps.

1. Install blowdown piping with ball valve at each wye strainer or suction diffuser. Extend piping to nearest drain.

H. Install flexible pump connectors per Section 23 21 13 “Hydronic Piping” on suction and discharge sides of close-coupled and base-mounted pumps between pump casing and valves.

I. Install a single pressure gage at each pump. Connect to pump suction and discharge with isolation valves. Install at integral pressure-gage tappings where provided.

J. Install check valve and ball valve on each condensate pump unit discharge.

K. Install electrical connections for power, controls, and devices. Electrical power and control wiring and connections are specified in Division 26.

L. Ground equipment according to Division 26.

3.3 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.

3.4 FIELD QUALITY CONTROL

A. Alignment:

1. Provide complete alignment by qualified millwright after installation in accordance with manufacturers’ written directions.
2. Set pumps on foundations, disconnect halves of flexible couplings, adjust shims until level using spirit level on the faces of the flexible coupling halves and on the suction and discharge flanges. Adjust to be level both horizontally and vertically.
3. Initial alignment: Adjust both angular and parallel alignment with dial indicator and adjust shims as required. After each adjustment, recheck both angular and parallel alignment. Continue until pump is in alignment both angular and parallel.
4. Tighten foundation bolts and grout base.
5. Once grout is set, ensure piping is filled and vented, and recheck both angular and parallel alignment and make adjustments as required. Firmly tighten foundation bolts.
6. Align flexible coupled pumps to within 0.003-inches.
7. Provide certified report.

END OF SECTION

SECTION 23 23 00

REFRIGERANT PIPING

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes refrigerant piping, fittings, valves, specialties and refrigerant used for split system air-conditioning and heat pump applications.

B. Refrigerant piping indicated is schematic only. Size piping and design the actual piping layout, including oil traps, double risers, and specialties, in accordance with the air-conditioning equipment manufacturer’s written instructions to ensure proper operation and compliance with warranties of connected equipment.

C. Refrigerant type shall be consistent with refrigeration equipment specified in other Sections.

1.2 REFERENCES

A. ASHRAE Standard: Comply with ASHRAE 22, "Safety Code for Mechanical Refrigeration."

B. ASME Standard: Comply with ASME B31.5, "Refrigeration Piping."

C. UL Standard: Provide products complying with UL 207, "Refrigerant-Containing Components and Accessories, Nonelectrical"; or UL 429, "Electrically Operated Valves."

1.3 ACTION SUBMITTALS

A. Product Data: For each type of valve and refrigerant piping specialty indicated.
   1. Include pressure drop, based on manufacturer's test data, for the following:
      a. Thermostatic expansion valves.
      b. Solenoid valves.
      c. Hot-gas bypass valves.
      d. Filter dryers.
      e. Strainers.
      f. Pressure-regulating valves.
   2. Include Air-conditioning manufacturer’s refrigerant pipe sizing criteria.

B. Shop Drawings: For each split-type air conditioning system, submit shop drawings showing the following:
   1. System identification.
   2. Isometric drawing of refrigerant liquid and vapor piping showing straight piping lengths, Indicate total equivalent length of liquid and vapor piping.

3. Show layout of refrigerant piping and specialties, including pipe, tube, and fitting sizes; flow capacities; valve arrangements and locations; slopes of horizontal runs; oil traps; double risers; wall and floor penetrations; and equipment connection details.
4. Show piping size and piping layout, including oil traps, double risers, specialties, and pipe and tube sizes to accommodate, as a minimum, equipment provided, elevation difference between compressor and evaporator, and length of piping to ensure proper operation and compliance with warranties of connected equipment.
5. Show interface and spatial relationships between piping and equipment.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Store piping with end caps in place to ensure that piping interior and exterior are clean when installed.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Refrigerants:
      a. Allied Signal, Inc./Fluorine Products; Genetron Refrigerants.
      b. DuPont Company; Fluorochemicals Div.
      c. Elf Atochem North America, Inc.; Fluorocarbon Div.
      d. ICI Americas Inc./ICI KLEA; Fluorochemicals Bus.
   2. Refrigerant Valves and Specialties:
      a. Climate & Industrial Controls Group; Parker-Hannifin Corp.; Refrigeration & Air Conditioning Division.
      b. Danfoss Electronics, Inc.
      c. Emerson Electric Company; Alco Controls Div.
      d. Henry Valve Company.
      e. Sporlan Valve Company.
      f. Alco

2.2 COPPER TUBE AND FITTINGS

A. Drawn-Temper Copper Tube: ASTM B 280, Type ACR.

B. Annealed-Temper Copper Tube: ASTM B 280, Type ACR.

C. Wrought-Copper Fittings: ASME B16.22.

D. Brazing Filler Metals:
    1. Copper-to Copper Joints: BCuP-5 or BCuP-6 without flux.
    2. Copper-to-Steel or Brass Joints: BAg-28 with non-acid flux.

2.3 VALVES

A. Diaphragm Packless Valves: 500-psig working pressure and 275 degrees F working temperature; globe design with straight-through or angle pattern; forged-brass or bronze body and bonnet, positive backseating, phosphor bronze and stainless-steel diaphragms, rising stem and handwheel, stainless-steel spring, nylon seat disc, and with solder-end connections.

B. Packed-Angle Valves: 500-psig working pressure and 275 degrees F working temperature; forged-brass or bronze body, forged-brass seal caps with copper gasket, back seating, rising stem and seat, molded stem packing, and with solder-end connections.

C. Packed Ball Valves: 500 psig working pressure and 300 degree F working temperature; two-piece, forged brass body with copper tube extensions, brass bonnet and seal cap, chrome-plated ball, Teflon seals, and neoprene ring stem seals.

D. Check Valves: 500 psig working pressure and 300 degree F working temperature; cast bronze or forged brass body, forged brass cap with neoprene seal, brass guide and disc holder, phosphor-bronze or stainless steel spring, and Teflon seat disc.

E. Solenoid Valves: Comply with ARI 760; 250 degrees F temperature rating and 500 psig working pressure; forged brass, with polytetrafluoroethylene valve seat, 2-way, straight-through pattern, and solder-end connections; manual operator; fitted with suitable NEMA 250 enclosure of type required by location, with 1/2-inch conduit adapter and holding coil.

F. Pressure Relief Valves: Straight-through or angle pattern, brass body and disc, neoprene seat, factory sealed and ASME labeled for standard pressure setting.

G. Thermostatic Expansion Valves: Comply with ARI 750; brass body with stainless-steel parts; thermostatic-adjustable, modulating type; size and operating characteristics as recommended by manufacturer of evaporator, and factory set for superheat requirements; solder-end connections; with sensing bulb, distributor having side connection for hot-gas bypass line, and external equalizer line.

H. Hot-Gas Bypass Valve: Pulsating-dampening design, stainless-steel bellows and polytetrafluoroethylene valve seat; adjustable; sized for capacity equal to last step of compressor unloading; with solder-end connections.

2.4 REFRIGERANT PIPING SPECIALITIES

A. Moisture/Liquid Indicators: 500-psig maximum working pressure and 200 degrees F operating temperature; all-brass body with replaceable, polished, optical viewing window with color-coded moisture indicator; with solder-end connections.

B. Permanent Filter-Dryer: 500-psig maximum operating pressure and 225 degrees F maximum operating temperature; steel shell and wrought-copper fittings for solder-end connections; molded-felt core surrounded by desiccant.

C. Flexible Connectors: 500-psig (3450-kPa) minimum operating pressure; seamless tin-bronze core, high-tensile bronze-braid covering, and solder-joint end connections; dehydrated, pressure tested, minimum 7 inches (180mm) long.

D. Mufflers: 500-psig operating pressure, welded-steel construction with fusible plug; sized for refrigeration capacity.

E. Straight- or Angle-Type Strainers: 500-psig working pressure; forged-brass or steel body with stainless-steel wire or brass-reinforced Monel screen of 80 to 100 mesh in liquid lines up to 1-1/8 inches, 60 mesh in larger liquid lines, and 40 mesh in suction lines; with screwed cleanout plug and solder-end connections.

2.5 RECEIVERS

A. Receivers, 6-Inch Diameter and Smaller: ARI 495, UL listed, steel, brazed, 500 psig pressure rating, with tappings for inlet, outlet, and pressure relief valve.

B. Receivers Larger Than 6-Inch Diameter: ARI 495, welded steel, tested and stamped according to ASME Boiler and Pressure Vessel Code: Section VIII; 500 psig pressure rating, with tappings for liquid inlet and outlet valves, pressure relief valve, and liquid-level indicator.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

A. Above ground: Type ACR drawn-copper tubing.

B. Below ground: Type ACR drawn-copper tubing. Type ACR annealed-copper tubing is permitted with no joints belowground.

3.2 PIPING INSTALLATION

A. Install refrigerant piping according to ASHRAE 15, American Refrigeration Institute (ARI), and refrigeration equipment manufacturer’s written recommendations.

B. Basic piping installation requirements are specified in Section 23 05 15 "Common Work Results for HVAC."

C. Install valves and specialties as indicated on Drawings. Each refrigerant circuit shall have a minimum of one field-installed moisture/liquid indicator and one field-installed permanent filter-dryer. Provide isolation valves for the replacement of each of these items.

D. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation. Use sleeves through floors, walls, or ceilings, sized to permit installation of full-thickness insulation.

E. Belowground, install copper tubing in Schedule 40 PVC protective conduit. Size conduit to permit easy replacement of largest refrigerant line. Vent conduit outdoors.

F. Install copper tubing in rigid or flexible conduit in locations where copper tubing will be exposed to mechanical injury.

G. When brazing, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion valve bulb.

H. Hanger, support, and anchor products are specified in Section 23 05 29 "Hangers and Supports for HVAC Piping and Equipment." Comply with requirements below for maximum spacing of pipe supports.

I. Install hangers with the following maximum spacing and minimum rod sizes:
   1. 5/8 Inch O.D.: Maximum span, 5 feet; minimum rod size, 1/4 inch.
   2. 3/4 Inch O.D.: Maximum span, 5 feet; minimum rod size, 1/4 inch.
   3. 7/8 Inch O.D.: Maximum span, 6 feet; minimum rod size, 1/4 inch.
   4. 1-1/8 Inch O.D.: Maximum span, 6 feet; minimum rod size, 1/4 inch.
   5. 1-3/8 Inch O.D.: Maximum span, 8 feet; minimum rod size, 3/8 inch.
   6. 1-5/8 Inch O.D.: Maximum span, 8 feet; minimum rod size, 3/8 inch.
   7. 2-1/8 Inch O.D.: Maximum span, 8 feet; minimum rod size, 3/8 inch.
   8. 2-5/8 Inch O.D.: Maximum span, 9 feet; minimum rod size, 3/8 inch.

J. Support vertical runs at each floor.

K. 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.

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

M. Install piping adjacent to machines to allow service and maintenance.

N. Install piping free of sags and bends.

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

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

Q. Arrange piping to allow inspection and service of refrigeration equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels if valves or equipment requiring maintenance is concealed behind finished surfaces.

R. Slope refrigerant piping as follows:
1. Install horizontal hot-gas discharge piping with a uniform slope downward away from compressor.
2. Install horizontal suction lines with a uniform slope downward to compressor.
3. Install traps and double risers to entrain oil in vertical runs.
4. Liquid lines may be installed level.

S. Identify refrigerant piping and valves according to Section 23 05 53 "Identification for HVAC Piping and Equipment."

T. Install sleeve seals for piping penetrations of concrete walls and slabs.

U. Install escutcheons for exposed piping penetrations of walls, ceilings, and floors.

3.3 PIPE JOINT CONSTRUCTION

A. Braze joints according to Section 23 05 15 "Common Work Results for HVAC."

B. Flow an inert gas (nitrogen or carbon dioxide) through pipe and fittings during brazing to prevent scale formation.

3.4 PERFORMANCE REQUIREMENTS

A. Line Test Pressure for Refrigerant R-134a:
1. Suction Lines for Air-Conditioning Applications: 115 psig.
2. Suction Lines for Heat-Pump Applications: 225 psig.
3. Hot-Gas and Liquid Lines: 225 psig.

B. Line Test Pressure for Refrigerant R-407C:
1. Suction Lines for Air-Conditioning Applications: 230 psig
2. Suction Lines for Heat-Pump Applications: 380 psig.
3. Hot-Gas and Liquid Lines: 380 psig.

C. Line Test Pressure for Refrigerant R-410A:
1. Suction Lines for Air-Conditioning Applications: 300 psig.
2. Suction Lines for Heat-Pump Applications: 535 psig.
3. Hot-Gas and Liquid Lines: 535 psig.

3.5 FIELD QUALITY CONTROL

A. Test and inspect refrigerant piping according to ASME B31.5, Chapter VI.
   1. Test refrigerant piping, specialties, and receivers. Isolate compressor, condenser, evaporator, and safety devices from test pressure.
   2. Test high- and low-pressure side piping of each system at not less than the lower of the pressure specified in Chapter “Refrigeration” of the applicable edition of the International Mechanical Code or the setting of pressure relief device protecting high and low side of system.
      a. System shall maintain test pressure at the manifold gage throughout the test.
      b. Test joints and fittings by brushing a small amount of soap and glycerine solution over joint.
      c. Fill system with nitrogen to raise to test pressure.

3.6 SYSTEM CHARGING

A. Charge system using the following procedures:
   1. Evacuate with a vacuum pump to less than 500 microns or the manufacturer’s specification, whichever is more stringent. Hold for 12 hours.
   2. Break vacuum with refrigerant gas.
   3. Charge system with a full-operating charge.

END OF SECTION

SECTION 23 25 00

HVAC WATER TREATMENT

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Closed Loop Chemical Treatment Systems.
   2. Open Loop Chemical Treatment Systems.
   3. Chemical treatment test equipment.
   4. HVAC water-treatment chemicals.

1.2 ACTION SUBMITTALS

A. Product Data: Include plan describing methods and chemicals proposed for use in system(s) cleaning and treatment. Include treatment system schematics showing connection locations to loop systems, sequences of operation, testing procedures, manufacturer’s literature for controllers, chemical feed pumps and chemicals. Include Material Safety Data Sheets for all proposed chemicals.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality-control test reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Chemicals: Treatment chemicals used in systems that are “bled” to sewer on a regular basis shall comply with all applicable waste control standards. All biocides must be EPA registered in the name of the Water Treatment Firm for application into the HVAC water system(s). All products shall have all ingredients listed on the storage container label and Material Safety Data Sheets.

B. HVAC Water-Treatment Service Provider Qualifications: An HVAC water-treatment service provider with a minimum of five years local experience, capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.6 WARRANTY

A. Special Guarantee: Provide a guarantee that the treated systems will remain scale and algae free for a period of one year when the provided treatment equipment and chemicals are used as directed. If scaling or fouling occurs when the provided treatment equipment and chemicals are used as directed the Water Treatment Firm shall clean the system(s) at no cost to the Owner.

B. Provide all parts and labor required to maintain the chemical treatment systems in good working order during the warranty period.

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 the environment.

B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.

C. Closed hydronic systems, shall have the following water qualities:
   1. pH: Maintain a value within 9.0 to 10.5.
   2. Soluble Copper: Maintain a maximum value of 0.20 ppm.
   3. Conductivity shall not reach over 3,000 ppm in uhmos.
   4. Microbiological Limits:
      a. Total Aerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
      b. Total Anaerobic Plate Count: Maintain a maximum value of 100 organisms/ml.
      c. Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
      d. Sulfate Reducers: Maintain a maximum value of 0 organisms/ml.

D. Open hydronic systems shall have the following water qualities:
   1. pH: Maintain a value within 8.4 to 9.0.
   2. "M" Alkalinity: Maintain a maximum value of 50 ppm.
   3. Calcium hardness: maintain a maximum of 800 ppm.
   4. Total hardness: maintain a maximum of 1,200 ppm.
   5. Log temperatures.

6. LSI: maintain between 1.8 and 2.4.
7. Soluble Copper: Maintain a maximum value of 0.20 ppm.
8. Conductivity shall not reach over 4,500 ppm in uhmos.
9. Microbiological Limits:
   a. Total Aerobic Plate Count: Maintain a maximum value of 10,000 organisms/ml.
   b. Total Anaerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
   c. Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
   d. Iron Bacteria: Maintain a maximum value of 0 organisms/ml.

2.2 OPEN LOOP (COOLING TOWER) SYSTEM

A. Chemical Controller: Microprocessor based pH and conductivity controller with watertight enclosure, 4-electrode 0-10,000 mS conductivity sensor with fouling compensation and alarm, differential 0-14 pH sensor with diagnostics, plumbing, flow switch, power cord and relays for control of bleed valve and chemical feed pumps, LCD display, interface for pH and conductivity monitoring by building control system. Controller shall be 120 VAC.
   1. Products: Subject to compliance with requirements, provide the following:
      a. Lakewood Nexsys
      b. Advantage
      c. Wallchem
      d. Pulsafeeder
      e. Prominent.

B. Chemical Solution Tanks:
   1. Products: Subject to compliance with requirements, provide the following:
      a. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
      b. Molded cover with recess for mounting pump.
      c. Capacity: 70 gal.

C. Chemical Solution Injection Pumps:
   1. Products: Subject to compliance with requirements provide one of the following:
      a. IWAKI EZ series.
      b. LMI Model 151.
      c. Pulsafeeder Model C Plus.
   2. Electronic metering pump
   3. Self-priming, positive-displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
   4. Minimum Capacity: 0.5 gallons per hour.
   5. Adjustable flow rate.
   6. Metal and thermoplastic construction.
   7. Built-in relief valve.

8. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Division 23 Section 23 05 13 "Common Motor Requirements for HVAC Equipment."

D. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints.

E. Injection Assembly:
   1. Quill: Minimum NPS 1/2 with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
   2. Ball Valve: Two-piece, stainless steel; selected to fit quill.
   3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
   4. Assembly Pressure/Temperature Rating: Minimum 600 psig at 200 deg F.

F. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, 2 pre-weighed C1010 mild steel coupons and 2 pre-weighed CDA 110 copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly. Provide stainless steel coupon at owner's direction.

G. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment, and that can attain water quality specified in Part 1 "Performance Requirements" Article.
   1. Scale Inhibitor: Chemical must capable of maintaining between 2.5 to 3.5 cycles of Concentration along with superior corrosion protection. Test should be non-proprietary and can be verified by the customer using standard test.
   2. Biocide: EPA registered, non-chlorine type, non-oxidizing and oxidizing type maintained at sufficient concentrations to prevent formation of slime and growth of algae.

H. Bleed Valve: Solenoid controlled, tower water bleed valve with built-in flow control. Provide one valve per controller.

2.3 CLOSED LOOP SYSTEMS

A. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, 1 pre-weighed C1010 mild steel coupon, and 1 pre-weighed CDA 110 copper coupon.

B. Chemicals:
   1. Cleaner: Alkaline based cleaner designed for the removal of oil, corrosion and other contaminants from closed loop piping systems and equipment.
   2. Corrosion Inhibitor: Nitrite type or molybdenum based, designed to prevent corrosion in closed loop piping.

PART 3 - EXECUTION

3.1 WATER ANALYSIS

A. Perform an analysis of supply water and provide full report to the owner to determine quality of water available at Project site. Provide analysis with report quarterly.

3.2 INSTALLATION

A. Install chemical storage tanks on 4-inch thick, reinforced concrete bases, level and plumb. Bases shall extend 6 inches beyond tank on all sides. Anchor chemical tanks to nearest wall or support to prevent tipping.

B. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible.

C. Furnish to and coordinate with Mechanical Contractor all items specified herein that are installed in piping systems.

D. Install water testing equipment on wall near water chemical application equipment.

E. Install interconnecting control wiring for chemical treatment controls and sensors. Coordinate conduit requirements with Electrical Contractor.

F. Mount sensors and injectors in piping circuits. Coordinate with Mechanical Contractor.

G. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.

H. 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 a gate or full-port ball isolation valves on inlet, outlet, and drain below feeder inlet.
  5. Install a swing check on inlet after the isolation valve.

3.3 CONNECTIONS

A. Piping installation requirements are specified in Division 22 and 23. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to equipment to allow service and maintenance.

C. Unless otherwise indicated, connect piping with unions and shut-off valves to allow equipment to be disconnected without draining piping.

D. Confirm applicable electrical requirements in Division 26 for connecting electrical equipment.

E. Ground equipment according to Division 26.

F. Connect wiring according to Division 26.

G. Interconnect flow switch dry contactors in Controller with condenser water pump starter. Open loop system bleed and chemical pump to be disabled when condenser pumps are not operating.

3.4 CLEANING

A. Provide cleaner as required to maintain the manufacturer’s recommended concentration for cleaning of the closed loop systems.

B. Circulate the cleaning solution for a minimum of 48 hours.

C. Drain and flush the system until all cleaning chemicals and suspended materials have been flushed from the system.

3.5 CHEMICAL ADDITION

A. Closed Loop Systems:
   1. Immediately after system testing, cleaning and flushing, add the required amount of corrosion inhibitor to reach the manufacturer’s recommended concentration.
   2. Install the corrosion coupons in the coupon rack after the initial chemical addition.

3.6 FIELD QUALITY CONTROL

A. Perform tests and inspections and prepare test reports.

B. Tests and Inspections:
   1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
   2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
   3. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
   4. 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.

5. 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.
6. 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.
7. Repair leaks and defects with new materials and retest piping until no leaks exist.

C. Operational Test: After the systems have been filled with water and the condenser pump(s) are operating, measure chemical treatment levels and verify proper operation of controller, chemical pumps and automatic bleed valve. Set the bleed and chemical feed rates to maintain the appropriate chemical levels.

D. Remove and replace malfunctioning units and retest as specified above.

E. At one-week intervals during the first four weeks following Substantial Completion, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis after each test. Advise Owner of changes necessary to adhere to Part 1 "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.

G. Corrosion Coupons:
1. Remove and replace the corrosion coupons at 90 day intervals.
2. Deliver the removed coupons to a certified laboratory for testing.
3. Return the coupons and certified analysis to the Owner’s representative.
4. If the coupon(s) from the system(s) show any noticeable metal loss the system water shall be tested and the appropriate action taken to prevent additional metal loss.

3.7 TRAINING

A. Train the Owner’s representative(s) in the proper methods for testing the system(s)’ water, chemical handling, adding chemicals to the system(s), adjustment, and use and maintenance of the controller(s) and chemical feed pumps. Training may be done during each of the regularly required visits.

3.8 MAINTENANCE SUPPLIES

A. Provide all chemicals, testing supplies, log sheets, laboratory analysis, and other consumables required to maintain the proper chemical balance in the system(s) during the warranty period.

END OF SECTION

SECTION 233113 - METAL DUCTS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Rectangular ducts and fittings.
2. Round ducts and fittings.
3. Sheet metal materials.
4. Sealants and gaskets.
5. Hangers and supports.

B. Related Sections:

1. Section 230713 “Duct Insulation”
2. Section 233300 "Air Duct Accessories"

1.2 PERFORMANCE REQUIREMENTS

A. Delegated Duct Design: Duct construction shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated in "Duct Schedule" Article.

1.3 ACTION SUBMITTALS

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

B. Shop Drawings:

1. Factory- and shop-fabricated ducts and fittings.
2. Duct layout indicating sizes, configuration, and static-pressure classes.
3. Fittings.
4. Penetrations through fire-rated and other partitions.
5. Equipment installation based on equipment being used on Project.
6. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
7. Hangers and supports, including methods for duct and building attachment, seismic restraints, and vibration isolation.

C. Delegated-Design Submittal:

1. Sheet metal thicknesses.
2. Joint and seam construction and sealing.
3. Reinforcement details and spacing.
4. Materials, fabrication, assembly, and spacing of hangers and supports.

5. Design Calculations: Calculations for selecting hangers and supports and seismic restraints.

1.4 INFORMATIONAL SUBMITTALS

A. Welding certificates.

1.5 QUALITY ASSURANCE

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

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.
3. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.

PART 2 - PRODUCTS

2.1 RECTANGULAR DUCTS AND FITTINGS

A. Elbow: Elbows shall have a set of single thickness turning vanes with extended trailing edges. Rectangular or sweep elbows without turning vanes are not permitted.

B. Elbow Configuration:
1. Radius Type RE 1, RE 2. And RE 3 with minimum 1.5 radius-to-diameter ratio.

C. Branch Configuration:
1. Rectangular Main to Rectangular Branch: 45-degree entry.
2. Rectangular Main to Round Branch: Conical (no spin-ins).

2.2 ROUND DUCTS AND FITTINGS

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

a. Lindab Inc.
b. McGill AirFlow LLC.
c. SEMCO Incorporated.
d. Sheet Metal Connectors, Inc.
e. Spiral Manufacturing Co., Inc.

B. Elbow Configuration:
1. Radius-to Diameter Ratio: Greater than or equal to 1.5.
2. Round Elbows, 12 Inches and Smaller in Diameter: Stamped or pleated.
3. Round Elbows, 14 Inches and Larger in Diameter: Standing seam or welded.

C. D. Branch Configuration:
1. Saddle taps are permitted in existing duct.
2. Conical or 45-degree lateral (no spin-ins)

2.3 SHEET METAL MATERIALS

A. General Material Requirements: Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.

1. Galvanized Coating Designation: G60.
2. Finishes for Surfaces Exposed to View: Mill phosphatized.
3. Sheet steel to be painted shall be Electro Galvanized Sheet Plate ASTM A653 Paint Lock Sheet Metal.

C. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316, as indicated in the "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in the "Duct Schedule" Article.

D. Aluminum Sheets: Comply with ASTM B 209 Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.

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.

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: 3 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).
11. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

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.
2. Type: S.
3. Grade: NS.
4. Class: 25.
5. Use: O.
6. For indoor applications, sealant shall have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealant shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

E. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

F. Round Duct Joint O-Ring Seals:

1. Seal shall provide maximum 3 cfm/100 sq. ft. at 1-inch wg and shall be rated for10-inch wg static-pressure class, positive or negative.
2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.5 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: All-thread or cadmium-plated steel rods and nuts.

B. Steel Cables: Not permitted.

C. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

D. Trapeze and Riser Supports:

1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
2. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.
3. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

B. Install ducts in maximum practical lengths.

C. Install ducts with fewest joints.

D. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

E. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

F. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

G. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

H. Where ducts pass through non-fire-rated interior partitions and exterior walls, 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.

I. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Section 233300 "Air Duct Accessories" for fire and smoke dampers.

J. 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."

K. Make connections to equipment with flexible connectors complying with Section 233300 "Air Duct Accessories."

3.2 INSTALLATION OF EXPOSED DUCTWORK

A. This section applies to ductwork exposed to view in normally occupied interior spaces and ductwork exposed to exterior weather conditions.

B. Round and rectangular ductwork shall be dual wall with fiberglass insulation between the outer duct and inner duct as manufactured by McGill AirFlow or approved equal.

C. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

D. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

E. 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.

F. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

G. Double wall ductwork shall continue completely through building envelope penetrations before transitioning to single wall ductwork construction.

3.3 HANGER AND SUPPORT INSTALLATION

A. 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.
6. Do not use powder-actuated concrete fasteners in occupied buildings.

B. Hanger Spacing: Install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

C. Hangers Exposed to View: Threaded rod and angle or channel supports.

D. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, or sheet metal screws; support at each floor and at a maximum interval of 16 feet.

E. Install attachments to structures. Select and size attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.4 DUCT CLEANING

A. Clean new duct segments as they are being installed.

B. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

3.5 DUCT SCHEDULE

A. SMACNA Seal Class:
1. C = seal only transverse joints
2. B = seal transverse joints and longitudinal seams.
3. A = seal above plus all applicable (wall) penetrations.

B. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:

C. Supply and return Ducts:

1. Ducts Connected to Air-Handling Units:

   a. Pressure Class: Positive 3-inch wg.
   b. Minimum SMACNA Seal Class A
   c. SMACNA Leakage Class for Rectangular: 6
   d. SMACNA Leakage Class for Round and Flat Oval: 3.

2. Ducts Connected to Equipment Not Listed Above:

   a. Pressure Class: Positive 3-inch wg.
   b. Minimum SMACNA Seal Class: A.
   c. SMACNA Leakage Class for Rectangular: 12.
   d. SMACNA Leakage Class for Round and Flat Oval: 6.

D. Exhaust Ducts:

1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:

a. Pressure Class: Negative 2-inch wg.
b. Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.
c. SMACNA Leakage Class for Rectangular: 12.
d. SMACNA Leakage Class for Round and Flat Oval: 6.

2. Ducts Connected to Fans Exhausting Laboratory and Process (ASHRAE 62.1, Class 3 and 4) Air:

a. Type 304, stainless-steel sheet.

1) Exposed to View: No. 3 finish.
2) Concealed: No. 2D finish.

b. Pressure Class: Positive or negative per design documents.
c. Minimum SMACNA Seal Class: A.
d. SMACNA Leakage Class: 3.

E. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:

1. Ducts Connected to Equipment:

a. Pressure Class: Positive or negative 2-inch wg.
b. Minimum SMACNA Seal Class: A.
c. SMACNA Leakage Class for Rectangular: 12.
d. SMACNA Leakage Class for Round and Flat Oval: 6.

F. Intermediate Reinforcement: Match Duct Materials.

G. Double wall Duct construction:
1. Supply and Outdoor Air Ducts and Plenums exposed in normally occupied indoor spaces shall be double-wall construction as described in the construction drawings.
2. Ductwork exposed to outdoor weather conditions shall be double wall construction as described in the construction drawings.

END OF SECTION

SECTION 23 33 00

DUCT ACCESSORIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes the following:
   1. Backdraft dampers.
   2. Barometric relief dampers
   3. Volume dampers.
   4. Fire dampers.
   5. Ceiling radiation fire dampers.
   6. Smoke and combination fire and smoke dampers.
   7. Turning vanes.
   8. Duct-mounting access doors.
   9. Flexible connectors.
   10. Flexible ducts.
   11. Acoustical flexible fiberglass ducts
   12. Duct silencers.
   13. Duct accessory hardware.
   14. Motorized dampers and actuators.
   15. Flange connectors.
   16. Remote damper operators.

B. Related Requirements:
   1. Applicable Division 23 and 28 Specification Sections for duct-mounting fire and smoke detectors.

1.2 ACTION SUBMITTALS

A. Product Data: Product Data: For each type of product.
   1. Backdraft dampers.
   2. Barometric relief dampers
   3. Volume dampers.
   4. Fire dampers.
   5. Ceiling fire dampers.
   6. Combination fire and smoke dampers, including wiring diagrams.
   7. Turning vanes.

8. Duct-mounting access doors.
9. Flexible connectors.
10. Flexible ducts.
11. Duct silencers.
    a. For duct silencers, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings
12. Motorized dampers and actuators.
13. Flange connectors.
14. Remote damper operators.

B. Shop Drawings: For duct accessories. Include plans, elevations, sections, details, and attachments to other work.
1. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, required clearances, and method of field assembly into duct systems and other construction. Include the following:
    a. Special fittings.
    b. Manual volume damper installations.
    c. Control-damper installations.
    d. Fire-damper, smoke-damper, combination fire- and smoke-damper, ceiling, and corridor damper installations, including sleeves; and duct-mounted access doors and remote damper operators.
    e. Duct security bars.
    f. Wiring Diagrams: For power, signal, and control wiring.

1.3 INFORMATIONAL SUBMITTALS

A. Test reports for combination fire and smoke dampers.

1.4 CLOSEOUT SUBMITTALS

A. Operating and maintenance data for fire dampers, ceiling fire dampers, and combination fire and smoke dampers, as applicable.

1.5 QUALITY ASSURANCE

A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and 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

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

2.2 SHEET METAL MATERIALS

A. Galvanized Sheet Steel: Lock-forming quality; complying with ASTM A 653/A 653M and having G60 or G90 coating designated; ducts shall have mill-phosphatized finish for surfaces exposed to view.

B. Stainless Steel: ASTM A 480/A 480M.

C. Aluminum Sheets: 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: ASTM B 209, alloy 6061, temper T6.

E. Reinforcement Shapes and Plates: Galvanized-steel reinforcement on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

F. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.3 BACKDRAFT DAMPERS

A. Manufacturers:
1. Air Balance, Inc.
2. Duro Dyne Corp.
3. Greenheck.
4. Penn Ventilation Company, Inc.
5. Tamco.
6. Honeywell.
7. Vent Products Company, Inc.

B. Description: Multiple-blade, parallel action gravity-type, counter-balanced, with blades of maximum 6-inch width, with sealed edges, assembled in rattle-free manner with 90-degree stop, steel ball bearings, and axles; adjustment device to permit setting for varying differential static pressure.

C. Frame: 0.052-inch- thick, galvanized sheet steel, with welded corners and mounting flange as required for application.

D. Blades: 0.050-inch- thick aluminum sheet.

E. Blade Seals: Vinyl or Neoprene.

F. Blade Axles: Galvanized steel.

G. Tie Bars and Brackets: Galvanized steel.

H. Adjustment Device: Adjustable counterweight or adjustable spring.

2.4 BAROMETRIC RELIEF DAMPERS

A. Manufacturers:
   1. Air Balance, Inc.
   2. Duro Dyne Corp.
   3. Greenheck.
   4. Penn Ventilation Company, Inc.
   5. Tamco
   6. Honeywell

B. Suitable for horizontal or vertical mounting.

C. Maximum Air Velocity: 1000 fpm.

D. Maximum System Pressure: 2-inch wg.

E. Frame: Hat-shaped, 0.094-inch thick, galvanized sheet steel, with welded corners or mechanically attached and mounting flange.

F. Blades:
   1. Multiple, 0.025-inch thick, roll-formed aluminum
   2. Maximum Width: 6 inches
   3. Action: Parallel.
   4. Balance: Gravity.

G. Blade Seals: Neoprene.

H. Blade Axles: Galvanized steel.

I. Tie Bars and Brackets:
   1. Material: Galvanized steel.
   2. Rattle free with 90-degree stop.

J. Return Spring: Adjustable tension.

K. Bearings: Stainless steel.

L. Accessories:
   1. Flange on intake.
   2. Adjustment device to permit setting for varying differential static pressures.

2.5 VOLUME DAMPERS

A. Manufacturers:
   1. Rossi or approved equal.

B. General: Factory fabricated, with required hardware and accessories. Stiffen damper blades for stability. Include locking quadrant type device to hold dampers in a fixed position without vibration by Rossi Air Flow or approved equal. Close duct penetrations for damper components to seal duct consistent with pressure class.

C. Standard Volume Dampers: Multiple-opposed blade type in rectangular applications, and single-blade in round applications, standard leakage rating, and suitable for horizontal or vertical applications.
   1. Steel Frames: Hat-shaped, galvanized sheet steel channels, minimum of 0.064 inch thick, with mitered and welded corners; frames with flanges if indicated for attaching to walls and flangeless frames if indicated for installing in ducts.
   2. Roll-Formed Steel Blades: 0.064-inch- thick, galvanized sheet steel.
   3. Blade Axles: Galvanized steel.
   4. Bearings: Oil-impregnated bronze.
   5. Tie Bars and Brackets: Galvanized steel.

D. Volume Dampers in Rectangular, Metal Product Conveying Ductwork: Multiple-opposed blade type, low leakage rating per AMCA 500, and suitable for horizontal or vertical applications.
   1. Frames: Hat-shaped, channels, same material as ductwork, with mitered and welded corners; frames with flanges for attaching to ducts.
   2. Blades: Airfoil shaped, same material as ductwork.
   3. Blade Axles: Same material as ductwork.
   4. Bearings: Oil-impregnated bronze or molded synthetic.
   5. Tie Bars and Brackets: Galvanized steel mounted outside of airstream.
   6. Seals: Neoprene on both blades and shafts.
   7. Blades Edge: Neoprene, extruded double edge design with inflatable pocket.
   8. Jamb: Stainless steel, flexible, compressible type.

E. Volume Dampers in Round, Metal Product Conveying Ductwork: Single-blade, low leakage rating per AMCA 509, suitable for horizontal or vertical applications.
   1. Frames: Channels, same material as ductwork with welded seams; frames with flanges for attaching to ducts.
   2. Blades: Stiffened, same material as ductwork.
   3. Blade Axles: Same material as ductwork.

4. Bearings: Oil-impregnated bronze or grease lubricated ball bearings, bolted to frame.
5. Blade Stop: Same material as ductwork.
6. Seals: Neoprene on both blades and shafts.
7. Jackshaft for Multiple-Damper Assemblies: 1-inch- diameter, galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple- damper assemblies.

F. Damper Hardware: Zinc-plated, die-cast core with dial and handle made of 3/32-inch-thick zinc-plated steel, and a 3/4-inch hexagon locking nut. Include center hole to suit damper operating-rod size. Include elevated platform for insulated duct mounting.

2.6 BLAST GATES (CUT-OFFS)

A. Manufacturers:
1. Tate-Jones.
2. Approved equal.

B. General: Full cut-offs consisting of cast or fabricated housings with duct mounting collars and slide gates suitable for air volume control in metal product conveying ducts.
1. Materials: Housing and slide gates constructed of same materials as attached ductwork.
2. Exception: Cast aluminum housings may be used in galvanized steel duct systems.

C. Features: Fully retractable slide gates with handles and set screws to maintain balanced position.

2.7 FIRE DAMPERS

A. Manufacturers:
1. Air Balance, Inc.
2. Greenheck.
3. McGill AirFlow Corporation.
4. METALAIRE, Inc.
5. Nailor Industries Inc.
6. Penn Ventilation Company, Inc.
7. Pottorff.
8. Prefco Products, Inc.
9. Ruskin Company.
10. Vent Products Company, Inc.

B. General: Fire dampers shall be dynamic type and labeled according to UL 555.

C. Fire Rating: 1-1/2 hours.

D. Frame: Curtain type with blades outside airstream; fabricated with roll-formed, 0.034-inch- thick galvanized steel; with mitered and interlocking corners.

E. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.

F. Minimum Thickness: 18 gauge (0.052 inch thick) and of length to suit application.

G. Exceptions: Omit sleeve where damper frame width permits direct attachment of perimeter mounting angles on each side of wall or floor, and thickness of damper frame complies with sleeve requirements.

H. Mounting Orientation: Vertical or horizontal as indicated.

I. Blades: Roll-formed, interlocking, 0.034-inch- thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- thick, galvanized-steel blade connectors.

J. Blade Lock/Closure Spring: Include blade lock and stainless-steel closure spring.

K. Fusible Links: Replaceable, 165 degrees F rated.

2.8 CEILING RADIATION FIRE DAMPERS

A. Manufacturers:
1. Air Balance, Inc.
2. Greenheck.
3. McGill AirFlow Corporation.
4. METALAIRE, Inc.
5. Nailor Industries Inc.
6. Penn Ventilation Company, Inc.
7. Pottorff.
8. Prefco Products, Inc.
9. Ruskin Company.
10. Vent Products Company, Inc.

B. General: Labeled according to UL 555C; comply with construction details for tested floor- and roof-ceiling assemblies as indicated in UL's "Fire Resistance Directory."

C. Frame: Galvanized sheet steel, round or rectangular, style to suit ceiling construction.

D. Blades: Galvanized sheet steel with refractory insulation.

E. Fusible Links: Replaceable, 165 degrees F rated.

2.9 SMOKE AND COMBINATION FIRE AND SMOKE DAMPERS

A. Damper Manufacturers:
   1. Air Balance, Inc.
   2. Greenheck.
   3. Nailor Industries Inc.
   4. Penn Ventilation Company, Inc.
   5. Pottorff.

B. General Description: Damper and actuator tested and labeled according to UL 555S and UL 555. Rating as required for the application but not less than 1-1/2-hour rating.

C. Leakage classification shall be UL555S Class I or Class II.

D. Temperature Rating: Minimum 250 degrees F (350 degrees F in smoke removal applications).

E. Velocity and Pressure Rating: Minimum 2,000 FPM velocity and minimum 4 inches water gage pressure ratings in low velocity (less than or equal to 2,000 FPM) applications.

F. Thermal-Switch: Resettable, 165 degrees F rated.

G. Frame and Blades: 0.064-inch- thick, galvanized sheet steel.

H. Mounting Sleeve: Factory-installed, minimum 0.040-inch- thick, galvanized sheet steel; length to suit wall or floor application.

I. Damper Motors: Provide for two-position action.

J. Spring-Return Motors: Brushless DC motor controlled by an Application Integrated Circuit (ASIC). Provide position indicator. Equip with an integral spiral-spring mechanism. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.

K. Outdoor Motors and Motors in Outside-Air Intakes: Equip with gaskets and seals designed to make motors weatherproof. Operating temperature range shall be minus 22 degrees F to plus 122 degrees F.

L. Electrical Connection: 115 V, single phase, 60 Hz.

2.10 TURNING VANES

A. Manufactured Turning Vanes: Fabricate 1-1/2-inch- wide, single-vane, curved blades with extended trailing edge of galvanized sheet steel set 3/4 inch o.c.; support with bars perpendicular to blades set 2 inches o.c.; and set into vane runners suitable for duct mounting.

B. Manufacturers:
   1. Ductmate Industries, Inc.
   2. Duro Dyne Corp.
   3. METALAIRE, Inc.
   4. Ward Industries, Inc.

2.11 DUCT-MOUNTING ACCESS DOORS

A. General: Fabricate doors airtight and suitable for duct pressure class.

B. Door in Rectangular Duct: Double wall, duct mounting, square or rectangular; fabricated of galvanized sheet metal with insulation fill to match adjacent ductwork and thickness as indicated for duct pressure class. Where used in metal product conveying ducts, use same material as duct. Include vision panel indicated on Drawings. Include 1-by-1-inch butt or piano hinge and cam latches.

C. Manufacturers:
   1. American Warming and Ventilating.
   2. Ductmate Industries, Inc.
   3. Flexmaster U.S.A., Inc.
   4. Greenheck.
   5. McGill AirFlow Corporation.
   6. Nailor Industries Inc.
   7. Ventfabrics, Inc.
   8. Ward Industries, Inc.

D. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets. Where used in metal product conveying ducts, use same material as duct.

E. Provide number of hinges and locks as follows:
   1. Less Than 12 Inches Square: Secure with two sash locks.
   2. Up to 18 Inches Square: Two hinges and two sash locks.
   3. Up to 24 by 48 Inches: Three hinges and two compression latches with outside and inside handles.
   4. Sizes 24 by 48 Inches and Larger: One additional hinge.

F. Door in Round Duct: Double wall, duct mounting, and round; fabricated of galvanized sheet metal with insulation fill and 1-inch thickness. Where used in metal product conveying ducts, use same material as duct. Include cam latches.

G. Manufacturers:
   1. Ductmate Industries, Inc.
   2. Flexmaster U.S.A., Inc.

H. Frame: Galvanized sheet steel, with spin-in notched frame. Where used in metal product conveying ducts, use same material as duct.
   1. Seal around frame attachment to duct and door to frame with neoprene or foam rubber.

I. Insulation: 1-inch- thick, fibrous-glass or polystyrene-foam board.

2.12 FLEXIBLE CONNECTORS

A. Manufacturers:
   1. Ductmate Industries, Inc.
   2. Duro Dyne Corp.
   3. Ventfabrics, Inc.
   4. Ward Industries, Inc.

B. General: Metal flanges connected by flame-retardant or noncombustible fabrics, coatings, and adhesives complying with UL 181, Class 1. Provide with minimum 4-inches of exposed fabric.

C. Flexible Connector Fabric: Glass fabric double coated with neoprene.
   1. Minimum Weight: 26 oz./sq. yd.
   2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
   3. Service Temperature: Minus 40 to plus 200 degrees F.

2.13 FLEXIBLE DUCTS

A. Manufacturers:
   1. Atco Rubber Products, Inc.
   2. Flexmaster U.S.A., Inc.
   3. Genflex.
   4. Hart & Cooley, Inc.
   5. McGill AirFlow Corporation.
   6. Thermaflex.

B. Insulated-Duct Connectors: UL 181, Class 1, 2-ply vinyl film supported by helically wound, spring-steel wire; fibrous-glass insulation with minimum R-value of 4.2; metallized, fiberglass- reinforced, film laminate.

C. Pressure Rating: 6-inch wg positive and 1.0-inch wg negative.

D. Maximum Air Velocity: 4000 fpm.

E. Temperature Range: Minus 10 to plus 160 degrees F.

F. Flexible Duct Clamps: Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action, in sizes 3 through 18 inches to suit duct size.

2.14 ACOUSTICAL FLEXIBLE FIBERGLASS DUCTS

A. At all runouts to diffusers, flexible air duct for connection between duct mains and ceiling air diffusers shall be a factory fabricated assembly consisting of an inner sleeve, insulation, and an outer moisture barrier. The inner sleeve shall be constructed of an elastomeric compound reinforced with woven fiberglass banded to a vinyl coated spring steel wire supporting helix. A minimum of 1-1/2 inch thick fiberglass insulating blanket shall encase the inner sleeve and be sheathed with an outer moisture barrier of a reinforced metalized Mylar/neoprene laminate, or equal.

B. Acoustical performance of the acoustical flexible air duct shall be in accordance with Air Diffusion Council Flexible Air Duct Test FD72R1: Paragraph 3.2.1, Sound Attenuation. The test data shall be made by an accredited independent testing laboratory in accordance with the above testing procedure.

C. Maximum length to be 5 feet. The material shall be Casco Silentflex II Acoustical Flex Duct as manufactured by C.A. Schroeder Company, San Fernando, California or approved equal.

D. Sound attenuation (insertion loss) of the acoustical flexible air duct shall meet or exceed the values tabulated below:

Straight Duct Insertion Loss in Decibels per Length of 10 Feet with No Airflow

Acoustical Flexible Air Duct	**Straight Duct Insertion Loss, dB Octave Band Center Frequency (Hz)**						
Inner Diameter	125	250	500	000	000	000	000
6 Inches	5	10	18	2	2	0	3
8 Inches	4	9	17	2	2	8	0
12 Inches	3	7	15	2	2	6	8

2.15 DUCT SILENCERS

A. Manufacturers:
1. Commercial Acoustics Division
2. Industrial Acoustics Company
3. Rink Sound Control
4. Vibro-Acoustics

B. General: Silencers shall be of the size, configuration, capacity, and acoustic performance as scheduled on the Drawings. All silencers shall be factory fabricated and supplied by the same manufacturer.

C. Construction: Silencers shall be constructed in accordance with ASHRAE and SMACNA standards for the pressure and velocity classification specified for the air distribution system in which they are installed. Silencer materials, including acoustic media, shall have a maximum flamespread classification of 25 and a maximum smoke development rating of 50 when tested in accordance with ASTM E84, NFPA 255 or UL 723. Silencers shall be tested in accord with ASTM-E477.

D. Rectangular Silencers:
   1. Outer casing: Minimum 22 gauge galvanized steel construction. All external seams shall be lockformed and filled with mastic and shall be airtight up to 8” W.G. differential pressure.
   2. Interior Baffles: Airfoil shape, constructed of not less than 26 gauge perforated galvanized steel. Baffles shall be designed for minimal pressure drop and maximum attenuation.
   3. Natural Cotton Fiber Insulation: Media shall be 100% natural cotton fibers treated with an EPA registered, non-toxic borate solution, “flash dried” to provide resistance to mold mildew and fungi. Media shall comply with UL 181 and NFPA 90A. Media shall not cause or accelerate corrosion of aluminum or steel.
   4. Glass Fiber Insulation: Media shall be of acoustic quality, shot-free glass fiber insulation with long, resilient fibers bonded with a thermosetting resin. Glass fiber density and compression shall be as required to insure conformance with laboratory test data. Glass fiber shall be packed with a minimum of 5% compression during silencer assembly. Media shall be bacteria and fungus resistant, resilient such that it will not crumble or break, and conform to irregular surfaces. Media shall not cause or accelerate corrosion of aluminum or steel.
   5. No-Media Silencers: No-Media silencers shall not contain any absorptive media. Attenuation shall be achieved solely with controlled impedance membranes and broadly tuned resonators.
   6. Media Protection: Acoustic media shall be completely wrapped with a non-erosive, non- pregnable, cleanable mylar film to help prevent shedding, erosion, and impregnation of the acoustic media. The wrapped acoustic media shall be separated from the perforated metal by a factory installed ½” thick acoustically transparent spacer. The spacer shall be flame retardant and erosion resistant.

2.16 FLANGE CONNECTORS

A. Description: Factory-fabricated, slide-on transverse flange connectors, gaskets, and components.

B. Material: Galvanized steel.

C. Gage and Shape: Match connecting ductwork.

2.17 REMOTE DAMPER OPERATORS

A. Description: Cable system designed for remote manual damper adjustment. Provide with wall box where required or with adjustment mounted at air distribution device. See drawings.

B. Cable: Stainless steel.

C. Wall-Box Mounting: Recessed.

D. Wall-Box Cover-Plate Material: Stainless steel.

2.18 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.

2.19 MOTORIZED DAMPERS

A. Damper Manufacturers:
   1. Air Balance, Inc.
   2. American Warming and Ventilating.
   3. Flexmaster U.S.A., Inc.
   4. McGill AirFlow Corporation.
   5. METALAIRE, Inc.
   6. Nailor Industries Inc.
   7. Penn Ventilation Company, Inc.
   8. Vent Products Company, Inc.

B. Dampers: AMCA-rated, parallel or opposed-blade design; 0.1084-inch minimum, galvanized- steel frames with holes for duct mounting; damper blades shall not be less than 0.0635-inch galvanized steel with maximum blade width of 8 inches.

C. Blades shall be secured to 1/2-inch-diameter, zinc-plated axles using zinc-plated hardware, with nylon blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.

D. Operating Temperature Range: From minus 40 to plus 200 degrees F.

E. For standard applications, include optional closed-cell neoprene edging.

F. For low-leakage applications, use parallel or opposed-blade design with inflatable seal blade edging, or replaceable rubber seals, rated for leakage at less than 10 cfm per sq. ft. of damper area, at differential pressure of 4 inches wg when damper is being held by torque of 50 in-lbf, when tested according to AMCA 500D.

G. Actuator Manufacturer: Belimo.

H. Actuators: Direct-coupled type design for minimum 60,000 full-stroke cycles at rated torque.

I. Sizing: Size for running torque calculated as follows:
1. Parallel-Blade Damper: 7 inch-pounds/sq. ft. of damper.
2. Opposed-Blade Damper: 5 inch-pounds/sq. ft. of damper.
3. Coupling: V-bolt and V-shaped, toothed cradle.
4. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
5. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on non-spring-return actuators.
6. Power Requirements (Two-Position Spring Return): 120-V ac.
7. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
8. Temperature Rating: Minus 22 to plus 122 degrees F.
9. Run Time: Not more than 15 seconds or less than 5 seconds.

3.1 APPLICATION AND INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" or SMACNA’s “Round Industrial Duct Construction Standards,” as applicable for metal ducts.

B. Provide duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Provide duct accessories suitable for the pressure class of the ductwork to which it is attached.

D. Install backdraft dampers on exhaust fans or exhaust ducts nearest to outside and where indicated.

E. In lined ducts install volume dampers in a manner that avoids damage to and, erosion of duct liner.

F. Provide balancing dampers at points on supply, return, outside air and exhaust systems where branches lead from larger ducts as required for air balancing. Install at a minimum of two duct widths from branch takeoff.

G. Install turning vanes in all rectangular duct elbows having a 45-degree or greater bend and not provided with radiused inside and outside corners.

H. Provide test holes at fan inlets and outlets and elsewhere as indicated.

I. Mount duct smoke detectors in strict conformance with manufacturer's recommendations. Duct smoke detectors to be furnished and wired in accordance with Division 23 or 26.

J. Install fire and smoke dampers where required and indicated on Drawings according to manufacturer's UL-approved written instructions.

K. Install duct access doors on sides of ducts indicated on drawings to allow for inspecting, adjusting, and maintaining accessories and terminal units. Locate on side of duct with greatest clearance. Install as follows:
   1. On both sides of duct coils. Minimum head and hand access.
   2. Downstream from automatic control dampers. Minimum two hand access.
   3. Adjacent to fire dampers or combination fire and smoke dampers, providing access to reset or reinstall thermal switch. Minimum two hand access.
   4. Downstream of duct mounted equipment, e.g., humidifier grids, duct heaters. Minimum head and hand access.
   5. To interior of ducts for cleaning; before and after each change in direction, at maximum 50-foot spacing. Minimum two hand access.

L. Install the following sizes for duct-mounting, rectangular access doors:
   1. Two-Hand Access: 12 by 6 inches.
   2. Head and Hand Access: 18 by 10 inches.
   3. Install the following sizes for duct-mounting, round access doors:
   4. Two-Hand Access: 10 inches in diameter.
   5. Head and Hand Access: 12 inches in diameter.

M. Label access doors according to Division 23 Section 23 05 53 "Identification for HVAC Piping and Equipment".

N. Install flexible connectors immediately adjacent to equipment in ducts associated with fans and motorized equipment supported by vibration isolators. Provide sheet metal sunshields on exterior flexible connectors.

O. Connect terminal units to supply ducts with maximum 12-inch lengths of flexible duct. Do not use flexible ducts to change directions.

P. Connect air outlets to low pressure ducts with maximum 60-inch lengths of flexible duct indicated on Drawings. Provide support(s) to maintain minimum 1.5 x Diameter turn radius for bends. Maximum total bend permitted is 135 degrees.

Q. Secure inner liner of flexible ducts to metal ducts and collars with a stainless steel draw band equipped with a slotted hex nut operated worm drive.

R. Install duct test holes indicated and required for testing and balancing purposes.

S. Install duct silencers in accordance with the manufacturer's installation instructions to achieve performance of their published data.

3.2 ADJUSTING

A. Adjust duct accessories for proper settings.

B. Test fire and smoke dampers for proper action. Repair or replace defective components or wiring.

C. Final positioning of manual-volume dampers is specified in Division 23 Section 23 05 93 "Testing, Adjusting, and Balancing."

END OF SECTION

SECTION 23 34 23

HVAC POWER VENTILATORS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Centrifugal roof ventilators.
   2. Centrifugal wall ventilators.
   3. Ceiling-mounting ventilators and cabinet fans.
   4. In-line centrifugal fans.
   5. Filtered supply fan.
   6. Propeller Fans.
   7. Utility vent sets.

1.2 ACTION SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated and include the following:
   1. Certified fan performance curves with system operating conditions indicated.
   2. Certified fan sound-power ratings.
   3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
   4. Material gages and finishes, including color charts.
   5. Dampers, including housings, linkages, and operators.
   6. Dimensions and service clearance requirements.
   7. Roof Curbs.
   8. Fan Speed Controllers.

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   2. Wiring Diagrams: For power, signal, and control wiring.

1.3 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.4 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. AMCA Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA-Certified Ratings Seal.

C. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.

D. UL Standard: Power ventilators shall comply with UL 705. Power ventilators for restaurant exhaust applications shall comply with UL 762.

1.5 COORDINATION

A. Coordinate size and location of structural-steel support members.

B. Coordinate sizes and locations of concrete bases with actual equipment provided.

C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Project Altitude: Base fan-performance ratings on 1280 feet above sea level.

B. Operating Limits: Classify according to AMCA 99.

2.2 MANUFACTURERS

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

2.3 CENTRIFUGAL ROOF VENTILATORS

A. Description: Belt-driven or direct-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, curb base, and accessories.

1. Manufacturers:
   a. Acme Engineering & Mfg. Corp.
   b. Cook, Loren Company.
   c. Greenheck Fan Corp.

B. Housing: Removable, spun-aluminum, down-discharge dome top and outlet baffle; square, one-piece, aluminum base with venturi inlet cone. Provide upblast type where scheduled on Drawings.

C. Fan Wheels: Aluminum hub and wheel with backward-inclined blades.

D. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:
   1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
   3. Pulleys: Cast-iron, adjustable-pitch motor pulley.
   4. Fan and motor isolated from exhaust airstream.

E. Accessories (As scheduled):
   1. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted outside fan housing, factory wired through an external LFMC conduit.
   2. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
   3. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
   4. Motorized Dampers: Where scheduled on Drawing, parallel-blade dampers mounted in curb base with Belimo 2-position, line-voltage electric actuator; wired to close when fan stops.
   5. Motor speed controllers.

F. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch- thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch wood nailer. Size as required to suit roof opening and fan base.
   1. Configuration: Self-flashing without a cant strip, with mounting flange.
   2. Overall Height: 12 to 14 inches.
   3. Pitch Mounting: Manufacture curb for roof slope.
   4. Damper Tray: Provide damper tray in roof curb where dampers are indicated to be provided with ventilators.
   5. Sound Curb: Curb with sound-absorbing insulation matrix.
   6. Metal Liner: Galvanized steel.
   7. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.
   8. Vented Curb: Unlined with louvered vents in vertical sides.
   9. Grease Trough: Continuously welded aluminum with removable lid mounted on subbase or curb.

2.4 CENTRIFUGAL WALL VENTILATORS

A. Description: Belt-driven or direct-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, and accessories.

1. Manufacturers:
    a. Acme Engineering & Mfg. Corp.
    b. Cook, Loren Company.
    c. Greenheck Fan Corp.

B. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; venturi inlet cone.

C. Fan Wheel: Aluminum hub and wheel with backward-inclined blades.

D. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:
1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
3. Pulleys: Cast-iron, adjustable-pitch motor pulley.
4. Fan and motor isolated from exhaust airstream.

E. Accessories (As scheduled):
1. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted outside fan housing, factory wired through external LFMC conduit.
2. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
3. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in wall sleeve; factory set to close when fan stops.
4. Motorized Dampers: Parallel-blade dampers mounted in curb base with 2-position, line voltage, electric actuator; wired to close when fan stops, where scheduled on Drawings.
5. Motor speed controllers.

2.5 CEILING-MOUNTING VENTILATORS AND CABINET FANS

A. Description: Centrifugal fans designed for installing in ceiling or wall, or for concealed in-line applications.
1. Manufacturers:
    a. Cook, Loren Company.
    b. Greenheck Fan Corp.

B. Housing: Steel, lined with acoustical insulation.

C. Fan Wheel: Centrifugal wheels directly mounted on motor shaft. Fan shrouds, motor, and fan wheel shall be removable for service.

D. Grille: Aluminum, louvered grille with flange on intake and thumbscrew attachment to fan housing.

E. Electrical Requirements: Junction box for electrical connection on housing and receptacle for motor plug-in.

F. Accessories (As scheduled):
1. Isolation: Rubber-in-shear vibration isolators.
2. Manufacturer's standard roof cap with curb or wall cap, and transition fittings.

2.6 IN-LINE CENTRIFUGAL FANS

A. Description: In-line, belt-driven centrifugal fans consisting of housing, wheel, outlet guide vanes, fan shaft, bearings, motor, drive assembly, mounting brackets, and accessories.
1. Manufacturers:
a. Cook, Loren Company.
b. Greenheck Fan Corp.
c. Hartzell Fan, Inc.

B. Housing: Square, galvanized steel frame with galvanized removable side panels, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or suspended mounting.

C. Direct-Driven Units: Motor encased in housing outside of airstream, factory wired to disconnect switch located on outside of fan housing.

D. Belt-Driven Units: Motor mounted on adjustable base, with adjustable sheaves, enclosure around belts within fan housing, and lubricating tubes from fan bearings extended to outside of fan housing. Extended lubricating tubes are not required if permanently lubricated ball bearings are provided.

E. Fan Wheels: Aluminum, backward-inclined blades welded to aluminum hub.

F. Accessories (As scheduled):
1. Companion Flanges: For inlet and outlet duct connections.
2. Fan Guards: 1/2- by 1-inch mesh of galvanized steel in removable frame. Provide guard for inlet or outlet for units not connected to ductwork.
3. Motor and Drive Cover (Belt Guard): Coated steel to match cabinet.
4. Motor speed controllers.

2.7 FILTERED SUPPLY FANS

A. Description: Factory-fabricated, -assembled, -tested, and –finished, direct or belt driven, centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly and accessories.
1. Manufacturers:
a. Acme Engineering & Mfg. Corp.
b. Cook, Loren Company.
c. Greenheck Fan Corp.

B. Housing: Formed and reinforced, removable, galvanized steel panels, attached to a galvanized steel fan base, with insulated top cover, outside-air hood and washable aluminum filter.

C. Fan: DWDI, centrifugal, forward curved type of painted steel with scroll housing.

D. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:
1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
3. Pulleys: Cast-iron, adjustable-pitch motor pulley.
4. Fan and motor isolated from exhaust airstream.

E. Accessories (As scheduled):
1. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted outside fan housing, factory wired through an external LFMC conduit.
2. Motor speed controllers.

F. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch- thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch wood nailer. Size as required to suit roof opening and fan base.
1. Configuration: Self-flashing without a cant strip, with mounting flange.
2. Overall Height: 12 to 14 inches.
3. Pitch Mounting: Manufacture curb for roof slope.

2.8 PROPELLER FANS

A. Description: Belt-driven or direct-driven propeller fans consisting of a fan support frame, venturi, propeller, fan shaft, bearings, motor, drive assembly, and accessories.

B. Manufacturers:
1. Acme Engineering & Mfg. Corp.
2. Cook, Loren Company.
3. Greenheck Fan Corp.

C. Venturi: Heavy-gage, painted steel, with welded corners; formed venturi inlet cone.

D. Support Frame: Heavy-gage steel designed to securely support the motor and propeller.

E. Propeller: Formed Steel or aluminum, or cast aluminum blades as indicated, securely fastened to a steel or aluminum hub. Entire propeller assembly to be statically and dynamically balanced.

F. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features
1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.

2. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
3. Pulleys: Cast-iron, adjustable-pitch motor pulley.

G. Accessories (As scheduled):
1. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted outside fan housing, factory wired through external LFMC conduit.
2. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
3. Shutter: Counterbalanced, parallel-blade, backdraft shutter mounted in wall sleeve; factory set to close when fan stops.
4. Motorized Shutter: Parallel-blade shutter mounted in wall sleeve with 2-position, line voltage, electric actuator; wired to close when fan stops, where scheduled on Drawings.
5. Wall Sleeve: Galvanized steel or aluminum, as indicated, sleeve with fixed exterior flange and adjustable interior flange for mounting fan through wall.
6. OSHA Wire Guard: Painted steel designed to provide OSHA compliant protection from fan.
7. Weather Hood: Galvanized steel hood with bird screen sized to prevent moisture entrainment on intake applications.
8. Shutter Guard: Painted steel or aluminum, as indicated on drawings, designed to protect shutter from vandalism or damage.
9. Motor speed controllers.

2.9 UTILITY VENT SETS

A. Description: Factory-fabricated, -assembled, -tested, and –finished, direct-or belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, support structure, and accessories.
1. Manufacturers:
   a. Aerovent; a Twin City Fan Company.
   b. Buffalo Forge Co./Howden Fan Co.
   c. Cook, Loren Company.
   d. New York Blower Company (The).
   e. Greenheck

B. Housing: Formed and reinforced galvanized steel or aluminum as schedules on Drawings, curved scroll housings with shaped cutoff, spun-metal inlet bell, and doors or panels to allow access to internal parts and components.
1. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
2. Fabrication Class: AMCA 99, Class as scheduled.
3. Special Coatings: Refer to schedule on Drawings.

C. Wheels:
   1. Backward-Inclined Fan Wheels: Steel or aluminum, as scheduled on Drawings, construction with curved inlet flange, back plate, backward-inclined blades welded or riveted to flange and back plate; cast-iron or cast-steel hub riveted to back plate and fastened to keyed shaft with set screws.
   2. Forward-Curved Fan Wheels: Black-enameled or galvanized steel construction with inlet flange, back plate, shallow blades with inlet and tip curved forward in direction of airflow, mechanically secured to flange and back plate; cast-steel hub swaged to back plate and fastened to keyed shaft with set screws.
   3. Special Coatings: Refer to schedule on Drawings.

D. Shafts:
   1. Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.
   2. Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
   3. Designed to operate at no more than 70 percent of first critical speed to top of fan's speed range.

E. Bearings: Prelubricated and sealed shaft bearings, self-aligning, pillow-block-type.
   1. Ball-Bearing Rating Life: ABMA 9, L_{10} of 100,000 hours.
   2. Roller-Bearing Rating Life: AMBA 11, L_{10} of 100,000 hours.

F. Belt Drives:
   1. Description: Factory mounted, with final alignment and belt adjustment made after installation, 1.5 service factor.
   2. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
   3. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with motors larger than 5 hp. Select pulleys so pitch adjustment is at the middle of adjustment range at fan design conditions.
   4. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
   5. Motor Mount: Adjustable for belt tensioning.

G. Accessories (As scheduled):
   1. Weather Cover/Belt Guard: Galvanized-steel or aluminum sheet with ventilation slots, bolted to housing. Weather cover shall also serve as an OSHA-complaint belt guard.
   2. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
   3. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
   4. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.

5. Companion Flanges: Galvanized steel, for duct connections.
6. Inlet Screens: Galvanized-steel welded grid screen.
7. Motor speed controllers.

2.10 MOTORS

A. Comply with requirements in Division 23 Section 23 05 13 "Common Motor Requirements for HVAC Equipment."

B. Motor Type: As scheduled on Drawings.

2.11 SOURCE QUALITY CONTROL

A. 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.

B. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, "Laboratory Methods of Testing Fans for Rating."

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install power ventilators level and plumb.

B. Support cabinet fans, in-line centrifugal fans and utility vent sets using vibration isolators as indicated on Drawings. Vibration- control devices are specified in Section 23 05 48 "Vibration Controls for HVAC Piping and Equipment."

   1. Secure vibration controls to concrete bases using anchor bolts cast in concrete base.

C. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03.

D. Secure roof-mounting fans to roof curbs with cadmium-plated hardware. Refer to Division O7 for installation of roof curbs.

E. Ceiling Mounting Ventilators: Suspend units from structure; use steel wire or metal straps.

F. Support suspended units from structure using threaded steel rods and spring hangers having a static deflection of 1 inch.

G. Install units with clearances for service and maintenance, minimum 36-inches on all sides.

H. Label units according to requirements specified in Section 23 05 53 "Identification for HVAC Piping and Equipment."

3.2 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories.

B. Make final duct connections to cabinet fans, in-line centrifugal fans, and utility vent sets with flexible connectors. Flexible connectors are specified in Section 23 33 00 "Duct Accessories.

C. Install ducts adjacent to power ventilators to allow service and maintenance.

3.3 FIELD QUALITY CONTROL

A. Perform tests and inspections.
   1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:
   1. 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.

C. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Prepare test and inspection reports.

E. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Remove malfunctioning units, replace with new units, and retest.

F. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

G. Shut unit down and reconnect automatic temperature-control operators.

H. Refer to Division 23 Section 23 05 93 "Testing, Adjusting, and Balancing" for testing, adjusting, and balancing procedures.

I. Replace fan and motor pulleys as required to achieve design airflow.

J. Repair or replace malfunctioning units. Retest as specified above after repairs or replacements are made.

END OF SECTION

SECTION 23 34 33

AIR CURTAINS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes air curtains.

1.2 ACTION SUBMITTALS

A. Product Data: For each model indicated, provide dimensions, weights, capacities at scheduled conditions, required clearances, electrical requirements, components, and location and size of each field connection.

1.3 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.4 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. Comply with NSF 37, "Air Curtains for Entranceways in Food and Food Service Establishments."

1.5 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace air curtains that fail in materials and workmanship within two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Berner International.
2. Biddle Air Systems Limited.
3. Cambridge Engineering, Inc.

4. Disco Engineering, Inc.; Part of Tucson Transatlantic Trade, Inc.
5. Fantech.
6. King Company; a company of Mestek, Inc.
7. Loren Cook Company.
8. Marley Engineered Products.
9. Mars Air Products; Dynaforce Division.
10. Mars Air Products; Mars Air Door Division.
11. Mestek, Inc.; L. J. Wing Division.
12. Miniveil Air Systems.
13. Powered Aire, Inc.

2.2 MATERIALS

A. Housing Materials: Galvanized steel or aluminum with electrostatically applied epoxy enamel finish over powdered mirror or heavy-gage, electroplated-zinc steel with welded construction and polyester coated finish.

B. Intake Louvers: Integral part of the housing, mechanically field adjustable and capable of reducing air-outlet velocity by 60 percent with louver in totally closed position.

C. Discharge Nozzle: Integral part of the housing, wedge shaped, containing adjustable air-directional vanes with 40-degree sweep front to back.

2.3 FANS

A. Fans: Galvanized steel or aluminum, centrifugal, forward curved, double width, double inlet; statically and dynamically balanced.

B. Fan Drives: Direct.

2.4 MOTORS

A. Comply with the requirements in Division 23 Section 23 05 13 “Common Motor Requirements for HVAC Equipment.”

B. Motor Type: Resiliently mounted, continuous duty, totally enclosed, air over or totally enclosed, fan cooled, with integral thermal-overload protection.

C. Bearings: Permanently sealed, life-time, prelubricated, ball bearings.

D. Disconnect: Internal power cord with plug and receptacle.

2.5 ELECTRIC HEATING COILS

A. Coil Assembly: Comply with UL 1096.

B. Frame: Galvanized-steel frame.

C. Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium; surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.

D. Heating Elements: Open-coil resistance wire of 80 percent nickel and 20 percent chromium, supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.

E. Overtemperature Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or unit.

F. Secondary Protection: Load-carrying, manually reset or manually replaceable, thermal cutouts; factory wired in series with each heater stage.

G. Control Panel: Mounted with disconnecting means and overcurrent protection. Include the following controls:

1. Magnetic contactor.
2. Mercury contactor.
3. Solid-state stepless pulse controller.
4. Toggle switches; one per step.
5. Step controller.
6. Time-delay relay.
7. Pilot lights; one per step.
8. Airflow proving switch.

2.6 FILTERS

A. Washable Panel Filters: Removable, stainless-steel, baffle-type filters with spring-loaded fastening; with minimum 0.0781-inch- thick, stainless-steel filter frame.

B. Mounting Frames: Welded, galvanized steel with gaskets and fasteners and suitable for bolting together into built-up filter banks.

2.7 ACCESSORIES

A. Automatic Door Switch: Remotely installed in door area to activate air curtain when door opens and to deactivate air curtain when door closes.

B. Time-Delay Relay: Factory installed and adjustable to allow air curtain to operate from 1 to 300 seconds after door closes.

C. Motor-Control Panel: Complete with motor starter, 115-V ac transformer with primary and secondary fuses, terminal strip, and NEMA 250, Type 12 enclosure.

D. Mounting Brackets: Adjustable mounting brackets for drum-type roll-up doors.

E. Discharge Extension Neck: For ceiling-recessed installation.

2.8 SOURCE QUALITY CONTROL

A. Comply with AMCA 220, "Laboratory Methods of Testing Air Curtains for Aerodynamic Performance Ratings," for airflow, outlet velocity, and power consumption.

B. Comply with AHRI 410, "Forced-Circulation Air-Cooling and Air-Heating Coils," for components, construction, and rating.

C. Comply with NSF 37, "Air Curtains for Entranceways in Food and Food Service Establishments."

D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and use.

E. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install air curtains with clearance for equipment service and maintenance.

3.2 CONNECTIONS

A. Ground equipment according to Division 26.

B. Connect wiring according to Division 26.

3.3 FIELD QUALITY CONTROL

A. Testing: Perform the following field quality-control testing:
1. After installing air curtains completely, perform visual and mechanical check of individual components.
2. After electrical circuitry has been energized, start unit to confirm motor rotation and unit operation. Certify compliance with test parameters.

B. Repair or replace malfunctioning units. Retest units until satisfactory results are achieved. Operate electric element through each stage and verify proper operation of electrical connection.

C. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3.4 ADJUSTING

A. Adjust motor speed to achieve specified airflow.

B. Adjust discharge louver and dampers to regulate airflow.

C. Adjust air-directional vanes.

END OF SECTION

SECTION 23 36 00

AIR TERMINAL UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Fan-powered air terminal units.
   2. Shutoff, single-duct air terminal units.

1.2 ACTION SUBMITTALS

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

B. Shop Drawings: For air terminal units. Include plans, elevations, sections, details, and attachments to other work.

1.3 CLOSEOUT SUBMITTALS

C. Operation and maintenance data.

1.4 QUALITY ASSURANCE

D. 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.

E. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

F. ASHRAE Compliance: Applicable requirements in ASHRAE/IES 90.1, "Section 6 - Heating, Ventilating, and Air Conditioning."

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

G. Structural Performance: Hangers and supports shall withstand the effects of gravity and seismic loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and ASCE/SEI 7.

2.2 PARALLEL FAN-POWERED AIR TERMINAL UNITS

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

B. Configuration: Volume-damper assembly and fan in parallel arrangement inside unit casing with control components inside a protective metal shroud.

C. Casing: 0.034-inch steel, single wall.
   1. Casing Lining: Adhesive attached, 1/2-inch thick, coated, fibrous-glass duct liner complying with ASTM C 1071, nonporous foil liner cover, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
   2. Air Inlets: Round stub connections for duct attachment.
   3. Air Outlet: S-slip and drive connections.
   4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
   5. Fan: Forward-curved centrifugal, located at plenum air inlet.
   6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Volume Damper: Galvanized steel with flow-sensing ring and peripheral gasket and self-lubricating bearings.
   1. Maximum Damper Leakage: ARI 880 rated 3 percent of nominal airflow at 3-inch w.g. inlet static pressure.
   2. Damper Position: Normally open.

E. Velocity Sensors: Multipoint array with velocity sensors in cold air inlets.

F. Motor: ECM variable-speed dc brushless motors specifically designed for use with single phase, 60 hertz electrical input.
   1. Motor shall be complete and operated by an integrated controller/inverter that operates the wound stator and senses rotor position to electronically commutate the stator.
   2. Motors shall be designed for synchronous rotation. Rotor shall be permanent magnet type with near zero rotor losses.
   3. Motor shall have built-in soft start and soft speed change ramps.
   4. Motor shall be permanently lubricated with ball bearings.
   5. Motor shall be directly coupled to the blower.
   6. Motor shall maintain a minimum of 70 percent efficiency over its entire operating range.
   7. Provide a motor that is designed to overcome reverse rotation and not affect life expectancy.

G. Terminal unit manufacturer shall provide a factory installed PWM controller for DDC controlled fan cfm adjustment. The PWM controller shall be capable of receiving a 0-10 Vdc signal from the DDC controller (provided by the controls contractor) to control the fan cfm.

1. Fan-Motor Assembly Isolation: Rubber isolators.

H. Filters: Minimum arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. Material: Pleated cotton-polyester media having 90 percent arrestance and 7 MERV.
2. Thickness: 1 inch.

I. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.

1. Stage(s): Silicon Controlled Rectifier (SCR) controller to provide proportional control of the electric heating coil in response to the automatic control signal from the equipment controller.
2. Access door interlocked disconnect switch.
3. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
4. Nickel chrome 80/20 heating elements.
5. Airflow switch for proof of airflow.
6. Fan interlock contacts.
7. Fuses in terminal box for overcurrent protection (for coils more than 48 A).

J. Factory-Mounted and -Wired Controls: Electrical components mounted in control box with removable cover. Incorporate single-point electrical connection to power source.

1. Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.
2. Wiring Terminations: Fan and controls to terminal strip. Terminal lugs to match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.
3. Disconnect Switch: Factory-mounted, fuse type.

K. Control Panel Enclosure: NEMA 250, Type 1, with access panel sealed from airflow and mounted on side of unit.

L. Direct Digital Controls: Bidirectional damper operators and microprocessor-based controller and room sensor. Control devices shall be compatible with temperature controls specified in Section 23 09 23 "Instrumentation and Control for HVAC" and shall have the following features:

1. Damper Actuator: 24 V, powered closed, spring return open.

2. Terminal Unit Controller: Pressure-independent, variable-air-volume controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:
   a. Occupied and unoccupied operating mode.
   b. Remote reset of airflow or temperature set points.
   c. Adjusting and monitoring with portable terminal.
   d. Communication with temperature-control system specified in Section 23 09 23 "Instrumentation and Control for HVAC."

M. Room Sensor: Wall mounted, with temperature set-point adjustment and access for connection of portable operator terminal.

2.3 SERIES FAN-POWERED AIR TERMINAL UNITS

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

O. Configuration: Volume-damper assembly and fan in series arrangement inside unit casing with control components inside a protective metal shroud for installation above a ceiling

P. Casing: 0.034-inch steel single wall.
   1. Casing Lining: Adhesive attached,1/2-inch- thick, coated, fibrous-glass duct liner complying with ASTM C 1071, nonporous foil liner cover, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
   2. Air Inlets: Round stub connections for duct attachment.
   3. Air Outlet: S-slip and drive connections.
   4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
   5. Fan: Forward-curved centrifugal.
   6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

Q. Volume Damper: Galvanized steel with flow-sensing ring and peripheral gasket and self-lubricating bearings.
   1. Maximum Damper Leakage: ARI 880 rated, 3 percent of nominal airflow at 3-inch w inlet static pressure.
   2. Damper Position: Normally open.

R. Velocity Sensors: Multipoint array with velocity sensors in cold air inlets.

S. Motor: ECM variable-speed dc brushless motors specifically designed for use with single phase, 60 hertz electrical input.

1. Motor shall be complete and operated by an integrated controller/inverter that operates the wound stator and senses rotor position to electronically commutate the stator.
2. Motors shall be designed for synchronous rotation. Rotor shall be permanent magnet type with near zero rotor losses.
3. Motor shall have built-in soft start and soft speed change ramps.
4. Motor shall be permanently lubricated with ball bearings.
5. Motor shall be directly coupled to the blower.
6. Motor shall maintain a minimum of 70 percent efficiency over its entire operating range.
7. Provide a motor that is designed to overcome reverse rotation and not affect life expectancy.

T. Terminal unit manufacturer shall provide a factory installed PWM controller for DDC controlled fan cfm adjustment. The PWM controller shall be capable of receiving a 0-10 Vdc signal from the DDC controller (provided by the controls contractor) to control the fan cfm.

1. Fan-Motor Assembly Isolation: Rubber isolators.

U. Filters: Minimum arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. Material: Pleated cotton-polyester media having 90 percent arrestance and 7 MERV.
2. Thickness: 1 or 2 inches.

V. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.

1. Stage(s): Silicon Controlled Rectifier (SCR) controller to provide proportional control of the electric heating coil in response to the automatic control signal from the equipment controller.
2. Access door interlocked disconnect switch.
3. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
4. Nickel chrome 80/20 heating elements.
5. Airflow switch for proof of airflow.
6. Fan interlock contacts.
7. Fuses in terminal box for overcurrent protection for coils more than 48 A.
8. Factory-Mounted and -Wired Controls: Electrical components mounted in control box with removable cover. Incorporate single-point electrical connection to power source.

9. Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.
10. Wiring Terminations: Fan and controls to terminal strip. Terminal lugs to match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.
11. Disconnect Switch: Factory-mounted, fuse type.

W. Control Panel Enclosure: NEMA 250, Type 1, with access panel sealed from airflow and mounted on side of unit.

X. Direct Digital Controls: Bidirectional damper operators and microprocessor-based controller and room sensor. Control devices shall be compatible with temperature controls specified in Section 23 09 23 "Instrumentation and Control for HVAC" and shall have the following features:
1. Damper Actuator: 24 V, powered closed, spring return open.
2. Terminal Unit Controller: Pressure-independent, variable-air-volume controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:
    a. Occupied and unoccupied operating mode.
    b. Remote reset of airflow or temperature set points.
    c. Adjusting and monitoring with portable terminal.
    d. Communication with temperature-control system specified in Section 23 09 23 "Instrumentation and Control for HVAC."

Y. Room Sensor: Wall mounted, with temperature set-point adjustment and access for connection of portable operator terminal.

2.4 SHUTOFF, SINGLE-DUCT AIR TERMINAL UNITS

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

B. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.

C. Casing: 0.034-inch steel [single] wall.
1. Casing Lining: Adhesive attached, 1/2-inch thick, coated, fibrous-glass duct liner complying with ASTM C 1071, nonporous foil liner cover, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
2. Air Inlet: Round stub connection for duct attachment.
3. Air Outlet: S-slip and drive connections.

4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.

D. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

E. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

1. Maximum Damper Leakage: ARI 880 rated 3 percent of nominal airflow at 3-inch w.g. inlet static pressure.
2. Damper Position: Normally open.

F. Direct Digital Controls: Single-package unitary controller and actuator specified in Section 23 09 23 "Instrumentation and Control for HVAC."

G. Direct Digital Controls: Bidirectional damper operators and microprocessor-based controller and room sensor. Control devices shall be compatible with temperature controls specified in Section 23 09 23 "Instrumentation and Control for HVAC" and shall have the following features:

1. Damper Actuator: 24 V, powered closed, spring return open.
2. Terminal Unit Controller: Pressure-independent, variable-air-volume controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:
   a. Occupied and unoccupied operating mode.
   b. Remote reset of airflow or temperature set points.
   c. Adjusting and monitoring with portable terminal.
   d. Communication with temperature-control system specified in Section 23 09 23 "Instrumentation and Control for HVAC."
3. Room Sensor: Wall mounted, with temperature set-point adjustment and access for connection of portable operator terminal.

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. Steel Cables: Stainless steel complying with ASTM A 492.

D. 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.

E. Air Terminal Unit Attachments: Factory mounting brackets. Include spring isolators for fan powered equipment.

2.6 SOURCE QUALITY CONTROL

A. Factory Tests: Test assembled air terminal units according to ARI 880.
   1. Label each air terminal unit with plan number, nominal airflow, maximum and minimum factory-set airflows, coil type, and ARI certification seal.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."

B. Install air terminal unit level and plumb. Maintain sufficient clearance for normal service and maintenance.

C. Install wall-mounted thermostats.

D. Install in accordance with the manufacturer’s installation instructions.

3.2 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 or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
   1. Where practical, install concrete inserts before placing concrete.

C. All Hangers Exposed to View and fan powered terminal units: Threaded rod with angle or channel supports to factory mounting brackets.

D. Hangers for shutoff, single duct air terminal units: Stainless steel cables or threaded rods with angle and channel supports to factory mounting brackets.

E. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.3 SEISMIC-RESTRAINT-DEVICE INSTALLATION

A. Install hangers and braces designed to support the air terminal units and to restrain against seismic forces required by applicable building codes if designated by the structural engineer of record. Comply with ASCE/SEI 7.

B. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.

C. Install cables so they do not bend across edges of adjacent equipment or building structure.

D. Install cable restraints on air terminal units that are suspended with vibration isolators.

E. Install seismic-restraint devices using methods approved by an evaluation service member of the ICC Evaluation Service.

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

G. Drilling for and Setting Anchors:
   1. Identify position of reinforcing steel and other embedded items before drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
   2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
   3. Wedge Anchors: Protect threads from damage during anchor installation. Install heavy-duty sleeve anchors with sleeve fully engaged in the structural element to which anchor is to be fastened.
   4. Set anchors to manufacturer's recommended torque, using a torque wrench.
   5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

3.4 TERMINAL UNIT INSTALLATION

A. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."

B. Install air terminal units level and plumb. Maintain sufficient clearance for normal service and maintenance.

3.5 CONNECTIONS

A. Install air terminal unit to allow service and maintenance.

B. Connect discharge air ducts to shutoff, single duct air terminal units according to Section 23 31 13 "Metal Ducts.”

C. Make connections to fan powered air terminal units with flexible ducts and flexible connectors complying with requirements in Section 23 33 00 "Air Duct Accessories."

3.6 IDENTIFICATION

A. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Section 23 05 53 "Identification for HVAC Piping and Equipment" for equipment labels.

3.7 FIELD QUALITY CONTROL

A. Perform tests and inspections.
   1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:
   1. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
   2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Air terminal unit will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

3.8 STARTUP SERVICE

A. Perform startup service.
   1. Complete installation and startup according to manufacturer's written instructions.
   2. Verify that inlet duct connections are as recommended by air terminal unit manufacturer to achieve proper performance.
   3. Verify that controls and control enclosure are accessible.
   4. Verify that control connections are complete.
   5. Verify that nameplate and identification tag are visible.
   6. Verify that controls respond to inputs as specified.

3.9 TRAINING

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air terminal units.

END OF SECTION

SECTION 23 37 13

DIFFUSERS, REGISTERS, AND GRILLES

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Ceiling- and wall-mounted diffusers, registers, and grilles.

1.2 ACTION SUBMITTALS

A. Product Data: For each product indicated. Include materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.

B. Diffuser Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

C. Samples for Verification: Where specifically requested provide a sample for each exposed product and for each color and texture specified. Actual size of smallest diffuser indicated.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Anemostat; a Mestek Company.
   2. Krueger.
   3. Nailor Industries of Texas, Inc.
   4. Price Industries.
   5. Titus.
   6. Tuttle & Bailey.

2.2 MATERIALS

A. Material: Steel, aluminum, or stainless steel as indicated on Drawings.

B. Finish: Baked enamel, white unless otherwise indicated.

C. Mounting: As indicated on Drawings. Provide countersunk screws on surface mounted outlets.

D. Damper: Provide damper where indicated on Drawings.
1. Opposed-blade type on square or rectangular neck outlets.
2. Radial type on round neck outlets.
3. Match materials of register.

E. Accessories: As indicated on Drawings.

2.3 ROUND CEILING DIFFUSERS

A. Devices shall be specifically designed for variable-air-volume flows.

B. Material: Per schedule on Drawings.

C. Finish: Per schedule on Drawings.

D. Face Style: Four cone.

E. Mounting: Duct connection.

F. Accessories: Per schedule on Drawings.
1. Equalizing grid.
2. Plaster ring.
3. Safety chain.
4. Wire guard.
5. Sectorizing baffles.
6. Operating rod extension.

2.4 RECTANGULAR AND SQUARE CEILING DIFFUSERS

A. Devices shall be specifically designed for variable-air-volume flows.

B. Material: Per schedule on Drawings.

C. Finish: Per schedule on Drawings.

D. Face Style: Per schedule on Drawings.

E. Mounting: Per schedule on Drawings.

F. Dampers: Per schedule on Drawings.

G. Accessories: Per schedule on Drawings.
1. Equalizing grid.
2. Plaster ring.

3. Safety chain.
4. Wire guard.
5. Sectorizing baffles.
6. Operating rod extension.

2.5 LINEAR BAR DIFFUSERS

A. Devices shall be specifically designed for variable-air-volume flows.

B. Material: Per schedule on Drawings.

C. Finish: Per schedule on Drawings.

D. Frame: Per schedule on Drawings.

E. Mounting: Per schedule on Drawings.

F. Damper Type: Per schedule on Drawings.

G. Accessories: Per schedule on Drawings.

2.6 LINEAR SLOT DIFFUSERS

A. Devices shall be specifically designed for variable-air-volume flows.

B. Material - Shell: Per schedule on Drawings.

C. Material - Pattern Controller and Tees: Aluminum.

D. Finish - Face and Shell: Per schedule on Drawings.

E. Finish - Pattern Controller: Per schedule on Drawings.

F. Slot Width: Per schedule on Drawings.

G. Number of Slots: Per schedule on Drawings.

H. Length: Per schedule on Drawings.

I. Accessories: Per schedule on Drawings.

2.7 HIGH-CAPACITY DRUM LOUVER DIFFUSERS

A. Airflow Principle: Extended distance for high airflow rates.

B. Material: Aluminum, heavy gage extruded.

C. Finish: Per schedule on Drawings.

D. Gasket between drum and border.

E. Body: Drum shaped; adjustable vertically.

F. Blades: Individually adjustable horizontally.

G. Mounting: Per schedule on Drawings.

H. Accessories: Per schedule on Drawings.
1. Opposed-blade steel damper.
2. Duct-mounting collars with countersunk screw holes.

2.8 REGISTERS AND GRILLES

A. Material: Per schedule on Drawings.

B. Finish: Per schedule on Drawings.

C. Face Blade Arrangement: Per schedule on Drawings.

D. Rear-Blade Arrangement: Per schedule on Drawings.

E. Frame: Per schedule on Drawings.

F. Mounting Frame: Per schedule on Drawings.

G. Damper Type: Per schedule on Drawings.

H. Accessories: Per schedule on Drawings.

2.9 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 INSTALLATION

A. Install diffusers, registers, and grilles level and plumb.

B. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practicable.
1. Coordinate exact location with Architectural Reflected Ceiling Plan, where applicable.

2. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.

C. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.2 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 37 23

HVAC GRAVITY VENTILATORS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Louvered-penthouse ventilators.
   2. Hooded Ventilators.

1.2 ACTION SUBMITTALS

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

B. Shop Drawings: Include plans, elevations, sections, details, ventilator attachments to curbs, and curb attachments to roof structure.
   1. Show weep paths, gaskets, flashing, sealant, and other means of preventing water intrusion.

1.3 COORDINATION

A. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

PART 2 - PRODUCTS

2.1 PERFORMNCE REQUIREMENTS

A. Structural Performance: Ventilators shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated without permanent deformation of ventilator components, noise or metal fatigue caused by ventilator blade rattle or flutter, or permanent damage to fasteners and anchors. Wind pressures shall be considered to act normal to the face of the building.
   1. Wind Loads: Determine loads based on pressures as indicated on Drawings.

B. Seismic Performance: Ventilators, including attachments to other construction, shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
   1. The term "withstand" means "the unit will remain in place without separation of parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2.2 MATERIALS

A. Aluminum Extrusions: ASTM B 221, Alloy 6063-T5 or T-52.

B. Aluminum Sheet: ASTM B 209, Alloy 3003 or 5005 with temper as required for forming or as otherwise recommended by metal producer for required finish.

C. Galvanized-Steel Sheet: ASTM A 653/A 653M, G90 zinc coating, mill phosphatized.

D. Fasteners: Same basic metal and alloy as fastened metal or 300 Series stainless steel unless otherwise indicated. Do not use metals that are incompatible with joined materials.

1. Use types and sizes to suit unit installation conditions.
2. Use Phillips flat hex-head or Phillips pan-head screws for exposed fasteners unless otherwise indicated.

E. Post-Installed Fasteners for Concrete and Masonry: Torque-controlled expansion anchors made from stainless-steel components, with capability to sustain without failure a load equal to 4 times the loads imposed for concrete, or 6 times the load imposed for masonry, as determined by testing per ASTM E 488, conducted by a qualified independent testing agency.

F. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.

G. Structural Performance: Ventilators shall withstand the effects of gravity loads and wind loads and stresses without permanent deformation of ventilator components, noise or metal fatigue caused by ventilator blade rattle or flutter, or permanent damage to fasteners and anchors.

H. Water Entrainment: Limit water penetration through unit to comply with ASHRAE 62.1.

2.3 FABRICATION

A. Factory or shop fabricate gravity ventilators to minimize field splicing and assembly. Disassemble units to the minimum extent as necessary for shipping and handling. Clearly mark units for reassembly and coordinated installation.

B. Fabricate frames, including integral bases, to fit in openings of sizes indicated, with allowances made for fabrication and installation tolerances, adjoining material tolerances, and perimeter sealant joints.

C. Fabricate units with closely fitted joints and exposed connections accurately located and secured.

D. Fabricate supports, anchorages, and accessories required for complete assembly.

E. Perform shop welding by AWS-certified procedures and personnel.

2.4 LOUVERED PENTHOUSE VENTILATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Aerovent.
   2. Greenheck Fan Corporation.
   3. Loren Cook Company.
   4. PennBarry.

B. Construction: Welded assembly with 4-inch or 6-inch-deep louvers, mitered corners, and aluminum sheet roof unless galvanized steel is indicated on schedule.

C. Frame and Blade Material and Nominal Thickness: Extruded aluminum, of thickness required to comply with structural performance requirements, but not less than 0.080 inch for frames and 0.060 inch for blades.
   1. AMCA Seal: Mark units with the AMCA Certified Ratings Seal.
   2. Exterior Corners: Prefabricated corner units with mitered and welded blades and with mullions at corners.

D. Roof Curbs: Galvanized-steel sheet; with mitered and welded corners; 1-1/2-inch- thick, rigid fiberglass insulation adhered to inside walls; and 1-1/2-inch wood nailer. Size as required to fit roof opening and ventilator base. Slope to match roof slope.
   1. Configuration: Built-in cant and mounting flange.
   2. Overall Height: 8 inches unless noted otherwise.

E. Bird Screening: Aluminum, 1/2-inch- square mesh, 0.063-inch wire

F. Insect Screening: Aluminum, 18-by-16 mesh, 0.012-inch or Stainless-steel, 18-by-18 mesh, 0.009-inch wire.

G. Galvanized-Steel Sheet Finish:
   1. Surface Preparation: Clean surfaces of dirt, grease, and other contaminants. Clean welds, mechanical connections, and abraded areas and repair galvanizing according to ASTM A 780. Apply a conversion coating suited to the organic coating to be applied over it.
   2. Factory Priming for Field-Painted Finish: Where field painting after installation is indicated, apply an air-dried primer immediately after cleaning and pretreating.
   3. Baked-Enamel Finish: Immediately after cleaning and pretreating, apply manufacturer's standard finish consisting of prime coat and thermosetting topcoat, with a minimum dry film thickness of 1 mil for topcoat and an overall minimum dry film thickness of 2 mils.
      a. Color and Gloss: As selected by Architect from manufacturer's full range.

2.5 ROOF HOODED VENTILATORS

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

2. Greenheck Fan Corporation.
3. Loren Cook Company.
4. PennBarry.

B. Factory fabricated according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figures 6-6 and 6-7.

C. Materials: Aluminum unless galvanized steel is indicated on schedule; suitably reinforced.

D. Roof Curbs: Galvanized-steel sheet; with mitered and welded corners; 1-1/2-inch- thick, rigid fiberglass insulation adhered to inside walls; and 1-1/2-inch wood nailer. Size as required to fit roof opening and ventilator base.
   1. Configuration: Built-in cant and mounting flange.
   2. Overall Height: 8 inches unless noted otherwise

E. Bird Screening: Galvanized-steel, 1/2-inch- square mesh, 0.041-inch wire or Aluminum, 1/2-inch- square mesh, 0.063-inch wire.

F. Insect Screening: Aluminum, 18-by-16 mesh, 0.012-inch or Stainless-steel, 18-by-18 mesh, 0.009-inch wire.

G. Galvanized-Steel Sheet Finish:
   1. Factory Priming for Field-Painted Finish: Where field painting after installation is indicated, apply an air-dried primer immediately after cleaning and pretreating.
   2. Baked-Enamel Finish: Apply manufacturer's standard finish consisting of prime coat and thermosetting topcoat, with a minimum dry film thickness of 1 mil for topcoat and an overall minimum dry film thickness of 2 mils.
      a. Color and Gloss: As selected by Architect from manufacturer's full range.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install gravity ventilators level, plumb, and at indicated alignment with adjacent work.

B. Secure gravity ventilators to roof curbs with cadmium-plated hardware. Use concealed anchorages where possible. Refer to Section 07 72 00 "Roof Accessories."

C. Install gravity ventilators with clearances for service and maintenance.

D. Install perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated.

E. Install concealed gaskets, flashings, joint fillers, and insulation as installation progresses. Comply with Section 07 92 00 "Joint Sealants" for sealants applied during installation.

F. Label gravity ventilators according to requirements specified in Section 23 05 53 "Identification for HVAC Piping and Equipment."

G. Protect galvanized and nonferrous-metal surfaces from corrosion or galvanic action by applying a heavy coating of bituminous paint on surfaces that will be in contact with concrete, masonry, or dissimilar metals.

H. Repair finishes damaged by cutting, welding, soldering, and grinding. Restore finishes so no evidence remains of corrective work. Return items that cannot be refinished in the field to the factory, make required alterations, and refinish entire unit or provide new units.

END OF SECTION

SECTION 23 57 00

HYDRONIC HEAT EXCHANGERS FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Shell-and-tube heat exchangers.
   2. Plate heat exchangers.

1.2 ACTION SUBMITTALS

A. Product Data: For each model indicated, provide dimensions, weights, capacities at scheduled conditions, required clearances, method of field assembly, components, and location and size of each field connection.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. ASME Compliance: Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 01.

B. ANSI: Liquid to Liquid heat exchangers shall be tested and performance certified in accordance with ANSI/AHRI Standard 400.

1.6 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of domestic-water heat exchangers that fail in materials or workmanship within specified warranty period.
   1. Failures include, but are not limited to, the following:
      a. Structural failures including heat exchanger, storage tank, and supports.
      b. Faulty operation of controls.
      c. Deterioration of metals, metal finishes, and other materials beyond normal use.
   2. Warranty Period: Two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

2.2 SHELL AND TUBE HEAT EXCHANGERS

A. Manufacturers:
   1. Armstrong Pumps, Inc.
   2. ITT Corp; Bell & Gossett.
   3. Taco, Inc.

B. Construction:
   1. Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 01.
   2. Fabricate and label shell-and-tube heat exchangers to comply with "TEMA Standards."

C. Configuration: Straight tube with removable bundle and heads.

D. Shell Materials: Steel.

E. Head:
   1. Materials: Cast iron.
   2. Flanged and bolted to shell.

F. Tube:
   1. Seamless copper tubes.
   2. Tube diameter is determined by manufacturer based on service.

G. Tube Sheet Material: Steel.

H. Baffles: Steel.

I. Piping Connections:
   1. Inlet and outlet fluid connections, threaded drain, and vent connections.
   2. Factory fabricated of materials compatible with heat-exchanger shell. Attach tappings to shell before testing and labeling.

J. Support Saddles:
   1. Fabricated of material similar to shell.
   2. Foot mount with provision for anchoring to support.
   3. Fabricate attachment of saddle supports to pressure vessel with reinforcement strong enough to resist heat-exchanger movement during a seismic event when heat-exchanger saddles are anchored to building structure.

2.3 GASKETED PLATE HEAT EXCHANGERS

A. Manufacturers:
   1. Alfa Laval Thermal, Inc.
   2. Armstrong Pumps, Inc.
   3. ITT Corp; Bell & Gossett.
   4. Mueller, Paul Co.
   5. Tranter.

B. Configuration: Freestanding assembly consisting of frame support, top and bottom carrying and guide bars, fixed and movable end plates, tie rods, plates, individually removable plates and one-piece gaskets.

C. Frame:
   1. Capacity to accommodate 20 percent additional plates.
   2. Painted carbon steel with provisions for anchoring to support.

D. Top and Bottom Carrying and Guide Bars: Painted carbon steel, aluminum, or stainless steel.
   1. Fabricate attachment of heat-exchanger carrying and guide bars with reinforcement strong enough to resist heat-exchanger movement during a seismic event when heat-exchanger carrying and guide bars are anchored to building structure.

E. End-Plate Material: Painted carbon steel.

F. Tie Rods and Nuts: Steel or stainless steel.

G. Plate Material: 0.024 inch thick before stamping; Type 316 stainless steel.

H. Gasket Material: EPDM.

I. Piping Connections:
   1. Threaded port for NPS 2 and smaller. For larger sizes, furnish end-plate port with threaded studs suitable for flanged connection.

J. Enclose plates in a solid aluminum removable shroud.

2.4 BRAZED PLATE HEAT EXCHANGERS

A. Manufacturers:
   1. Alfa Laval Thermal, Inc.
   2. Armstrong Pumps, Inc.
   3. ITT Corp; Bell & Gossett.
   4. Mueller, Paul Co.
   5. Tranter.

B. Configuration: Brazed assembly consisting of embossed or pressed stainless-steel plates brazed together and two end plates, one with threaded nozzles and one with pattern-embossed plates.

C. Construction: Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 01.

D. End-Plate Material: Type 316 stainless steel.

E. Threaded Nozzles: Type 316 stainless steel.

F. Plate Material: Type 316 stainless steel.

G. Brazing Material: Copper or nickel.

2.5 ACCESSORIES

A. Hangers and Supports:
   1. Custom, steel supports for mounting on floor, wall or structural steel.

B. Factory or field-fabricated steel supports to ensure both horizontal and vertical support of heat exchanger.

C. Shroud: Aluminum sheet.

2.6 SOURCE QUALITY CONTROL

A. Factory Tests: Test and inspect heat exchangers according to ASME Boiler and Pressure Vessel Code, Section VIII, "Pressure Vessels," Division 01. Affix ASME label.

B. Hydrostatically test heat exchangers to minimum of one and one-half times pressure rating before shipment.

C. Heat exchangers will be considered defective if they do not pass tests and inspections.

D. Prepare and submit test and inspection reports

PART 3 - EXECUTION

3.1 HEAT EXCHANGER INSTALLATION

A. Examine areas for compliance with requirements for installation tolerances and for structural rigidity, strength, anchors, and other conditions affecting performance of heat exchangers.

B. Examine roughing-in for heat-exchanger piping to verify actual locations of piping connections before equipment installation.

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

D. Maintain manufacturer’s recommended clearances for service and maintenance. Install piping connections to allow service and maintenance of heat exchangers.

E. Install shell-and-tube heat exchangers on, and anchor to, saddle supports.

F. Install plate heat exchangers on, and anchor to, concrete base.

3.2 CONNECTIONS

A. Install shutoff valves at heat exchanger inlet and outlet connections.

B. Install relief valves on heat-exchanger heated-fluid connection and install pipe relief valves, full size of valve connection, to floor drain.

C. Install hose end valve to drain shell.

D. Install full size drain with shutoff valve in-line with the lowest connection of each circuit of plate heat exchangers.

E. If a plate heat exchanger is connected to an open loop system, a full sized backflush crossover must be provided.

F. Install piping adjacent to heat exchangers to allow space for service and maintenance of heat exchangers. Arrange piping for easy removal of heat exchangers.

G. Install thermometer on heat-exchanger inlet and outlet piping.

H. Install pressure gages on heat-exchanger inlet and outlet piping

3.3 SHELL-AND-TUBE-HEAT-EXCHANGER INSTALLATION

A. Equipment Mounting:
   1. Install heat exchangers on cast-in-place concrete equipment bases.

B. Install heat exchangers on saddle supports.

C. Heat-Exchanger Supports: Use factory-fabricated steel cradles and supports specifically designed for each heat exchanger.

3.4 GASKETED PLATE HEAT EXCHANGER INSTALLATION

A. Install gasketed-plate heat exchanger on custom-designed wall supports anchored to structure as indicated on Drawings.

B. Install metal shroud over installed gasketed-plate heat exchanger according to manufacturer's written instructions.

3.5 BRAZED PLATE HEAT EXCHNGE INSTALLATION

A. Install brazed-plate heat exchanger on custom-designed wall supports anchored to structure as indicated on Drawings.

3.6 FIELD QUALITY CONTROL

A. Perform the following tests and inspections with the assistance of a factory-authorized service representative:

1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

B. Heat exchanger will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports.

3.7 CLEANING

A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

END OF SECTION

SECTION 23 61 00

EVAPORATIVE COOLERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
    1. Evaporative coolers.

1.2 ACTION SUBMITTALS

A. Product Data:
    1. Provide dimensions, weights, capacities at scheduled conditions, required clearances, components, accessories, and electrical requirements.
    2. Location and size of each field connection.
    3. Detail mounting, securing, and flashing of roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
    4. Design of the support structure.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and Maintenance data.

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. Evaporative Coolers: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

C. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning" and Section 10 - "Other Equipment."

D. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.

1.6 WARRANTY

A. Manufacturer's standard warranty form in which manufacturer agrees to repair or replace components of evaporative coolers that fail in materials or workmanship within specified warranty period.
   1. Failures include, but are not limited to, the following:
      a. Fan, motor, drive shaft, bearings, and motor supports.
      b. Evaporative Media and support structure
      c. External-circuit circulating pump.
   2. Warranty Period: Two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

2.2 COMMERCIAL STYLE EVAPORATIVE COOLERS

A. Manufacturers:
   1. Adobe Air, Inc. Mastercool
   2. Phoenix Manufacturing, Inc.
   3. United Metal Products, Inc.
   4. Or equivalent upon written approval of Architect/Engineer and Owner in accordance with substitution procedures in Section 01 25 00.

B. Cabinet Design:
   1. Discharge Openings: Standard unit construction is to include horizontal or vertical air discharge as indicated on Drawings.
   2. Cabinet to be fabricated of 20 gauge hot dipped galvanized steel with electrostatically-applied polyester-epoxy powder-based coating.
   3. Each standard model is to include one (1) removable panel providing access to blower motor drive.

C. Blower Section:
   1. Fan: Forward-curved or backward-inclined type, rated according to AMCA 210; statically and dynamically balanced, galvanized-steel, centrifugal fan mounted on solid-steel shaft with one (1) set of heavy-duty, self-aligning, prelubricated ball bearings on each side of the fan wheel and an adjustable V-belt drive with matching motor sheaves and belts.
      a. Fan wheel and fan pulley shall be keyed to shaft.
   2. Motor: High efficiency type mounted on a heavy-gauge, adjustable base.
   3. Controls: Switches on thermostat as indicated on Drawings or as required per the sequence of operations.

D. Cooling Section:
1. Tank: 18 gauge, 304 stainless steel or hot dipped galvanized steel with electrostatically-applied polyester-epoxy powder-based coating.
2. Media: Glas-dek 12” deep glass mat, fluted, high efficiency evaporative media. Matched 2” thick distribution pad to aid in water dispersal. Media shall be U.L. approved with a UL 900 class 2 rating.
3. Water Distribution Header: Copper or PVC header pipe with ports drilled for proper water flow.
4. Pump: Heavy duty submersible pump with balancing valve on discharge for proper water flow and carry-over prevention.
5. Float Valve: Cast brass 3/8” float valve; commercial grade.
6. Saturating Efficiency: 88% minimum rated at 700 FPM maximum face velocity; 91% efficiency rated at 500 FPM face velocity.

2.3 INDUSTRIAL STYLE EVAPORATIVE COOLERS

A. Manufacturers:
1. AZ Evap
2. Energy Labs, Inc.
3. United Metal Products, Inc.
4. Or equivalent upon written approval of Architect/Engineer and Owner.

B. Cabinet & Frame:
1. Single wall, minimum 16-gauge, 304/316 stainless steel construction with stainless steel industrial hex-head fasteners to secure to the tubular steel frame.
2. Weather-tight roof assembly.
3. Supply air discharge as shown on the Drawings.
4. Provide one GFI receptacle on exterior of the unit.
5. Provide internal marine light in each section with weatherproof switch.
6. Base frame shall be full perimeter, 10 gauge, welded 304 stainless steel with C-channel steel cross members for supporting floor and major components. Integral steel frame shall be constructed so that exterior panels are not load bearing members.
7. Provide lifting lugs attached to frame as needed.
8. No part of the base frame shall be used as a reservoir to contain water.
9. Unit’s roof curbs, when needed, shall be furnished by the manufacturer and fabricated of 14-gauge stainless steel, welded, with an integral wood nailer.

C. Floor:
1. Provide 14 gage, continuously welded 304/ 316 stainless steel floor that spans the entire length and width of the evaporative cooler. Unit components such as reservoirs, sumps, fan, and motor bases shall be mounted above the flooring.
2. The floor shall be designed with adequate underbracing to eliminate “oil canning” from foot traffic inside the unit.

D. Access Door:
1. Provide hinged, double wall, thermally insulated and gasketed 304/316 stainless steel access doors.
2. Gaskets shall be automotive grade 100% memory bulb type.
3. Door hinges shall be industrial grade 304 stainless steel, continuous piano type.
4. Provide a minimum of two heavy-duty compression latches on each door, Ventlock 260 or equal, so that each door can be opened from the inside for safety of O&M personnel.
5. Access doors shall be sized so as to easily remove the largest piece of internal equipment without dismantling that piece of equipment.
6. Metal rain caps matching the finish of the cabinet shall be provided over each access door.

E. Supply Fan:
1. Fan Shaft: Shaft shall be made of stress-relieved, ground and polished stainless steel. Shaft critical speed shall be 20 percent higher than the maximum operating speed.
2. Fan Wheel: 316 stainless steel.
3. Fan Type: Airfoil centrifugal, AMCA Class 1.
4. Bearings: Anti-friction, self-aligning, pillow block greaseable ball bearings, rated for 200,000 hours L-10 life, with extended lube lines for easy access.
5. Drives: Belt drive with minimum horsepower capacity of 150% of nameplate horsepower. Sheave of non-adjustable type with removable machined bushings and keyed shaft, dynamically balanced at factory.
6. Motor Mount: Adjustable for belt tensioning.
7. Entire fan, motor and drive assembly shall be mounted on a stainless steel base and supported with spring vibration isolators.
8. Fan shall be tested and rated in accordance with AMCA standard 210.

F. Fan Motor & Drives:
1. Motor for supply fan shall be furnished and installed by the evaporative cooler manufacturer.
2. Motor speed shall be 1800 RPM maximum.
3. Service factor shall be 1.15 or greater and rated for continuous operation at full load amps.
4. Motor shall be cast iron “high efficiency” design and rated in accordance with NEMA test standard MG1-12.53a (1EEE 112 test standard, method B).
5. Ball bearings shall be cool running, anti-friction bearings with double-shielded lubrication parts on each side. Bearing life shall be 200,000 hours (AFBMNA “FF”, L-10).
6. Name plates shall be stamped with NEMA Standard information, bearing I.D. and lubrication instruction.
7. All sheaves, fixed or variable, shall not exceed the hp rating of the motor.

G. Vibration Control:
   1. Install fan/motor assembly on open-spring vibration isolators having a minimum of 1-inch static deflection and side snubbers.
   2. Provide flexible connector between fan housing and cabinet.

H. Direct Evaporative Cooling Section:
   1. Media:
      a. Media shall be GLASdek as manufactured by Munters Corp., or equal. UL 900, Class 2 rating, with a minimum evaporative effectiveness of 88 percent, designed for maximum entering air velocity of 500 feet per minute.
      b. Media shall be cross-fluted design, self-cleaning and unaffected by atmospheric dust or sand.
      c. Thickness shall be 12-inches in the direction of airflow, including 4-inch removable pre-evaporative section.
      d. Provide Type 304L stainless steel media holding rack.
      e. Design shall allow for no water carry over to the fan section.
   2. Recirculating Water Pump, self priming:
      a. Recirculating water pump shall be centrifugal, submersible type constructed of cast bronze with bronze or stainless steel trim.
      b. Pump capable of delivering 1.5 GPM per square foot of horizontal media area.
      c. Pump shall have suction strainer, thermal and low water cut-off protection.
   3. Sump Tank:
      a. Sump tank shall be made of minimum 16 gauge, Type 304 or 316 stainless steel with fill, drain and overflow connections.
      b. The reservoir/sump shall not be integral to the base frame or flooring. The sump shall be constructed as a separate component and secured in place on top of the unit flooring.
      c. Provide an adjustable float-operated brass valve for controlling the water level in the sump tank.
   4. Water Distribution Piping:
      a. Distribution piping for recirculating water shall be Type L copper throughout the entire unit.
      b. Distribution headers shall have manual valves for balancing of water flow over evaporative media.
   5. Flushing System:
      a. Provide a factory wired and plumbed, distribution header flushing system. The automated flush shall be fully adjustable, utilizing a low voltage time clock to sequence the flush cycles. Time clock shall be mounted in the Unit Control Panel.
      b. The flushing system shall provide a means of preventing the clogging of the header and an adjustable method of bleed off. A timed drain event from the sump is not an acceptable means of bleed.
      c. Provide a dedicated, internally mounted and wired normally closed solenoid valve for flushing, with manual ball valve for isolation.
   6. Protection of Dissimilar Metals
      a. Stainless material shall be properly isolated to prevent dissimilar metal contact.

I. Intake Louvers:
   1. Type 304 or 316 stainless steel outside air intake with 4-inches deep, 45 degree rainproof, horizontal, drainable louvers housed in a 304 stainless steel frame.
   2. Provide 1/2-inch mesh, bird screen mounted in a frame.

J. Bolts, nuts and washers utilized shall be Type 410 stainless steel.

K. Unit Control Panel & Electrical:
   1. Provide NEMA 3R type panel factory-mounted and wired.
   2. Control and power wiring shall be in accordance with UL and NEC requirements.
   3. Provide single point power connection.
   4. Provide unit thermal magnetic disconnect switch, required 120 volt power transformers and 24 volt control transformers, fuses and fuse clips, marked terminal strips and NEMA rated or IEC magnetic starters with overload protection in each phase for three phase motors.
   5. Provide a safety switch at fan access door to automatically deenergize fan upon opening door.
   6. Provide a manual switch on exterior of unit adjacent to fan access door to enable maintenance personnel to deenergize fan prior to entering fan section.
   7. Provide a remote-mounted low voltage HIGH-COOL/LOW-COOL/HIGH-VENT/LOW-VENT/OFF mode switch. Furnish cabling of sufficient wire size to enable the mode switch to be installed up to 150 feet away from the Unit Control Panel.
      a. When the mode switch is placed in the HIGH or LOW COOL position, the fan and pump shall both operate. The fan speed shall be high or low depending on the switch setting.
      b. When the mode switch is placed in HIGH or LOW VENT position, the fan shall operate and the pump shall be deenergized. The fan speed shall be high or low depending on the switch setting.
      c. When the mode switch is placed in OFF position, fan and pump shall be deenergized.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install ground or roof-mounted units as indicated on drawings on neoprene pads with 0.15 inch static deflection; refer to Division 23 Section 23 05 48 "Mechanical Vibration and Seismic Controls."

B. Install roof-mounted units on curbs complying with requirements in Division 07.

C. Install ground mounted coolers on concrete base. Concrete base is specified in Division 23 Section 23 05 15 “Common Work Results for HVAC,” and concrete materials and installation requirements are specified in Division 03.

D. Concrete Bases: Anchor coolers to concrete bases with stainless steel anchor bolts.
  1. Install dowel rods to connect concrete base to concrete floor, where applicable. Unless otherwise indicated, install dowel rods on 18-inch centers around full perimeter of the base.
  2. For equipment supported on structural slab, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
  3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
  4. Cast-in-place concrete materials and placement requirements are specified in Division 03.
  5. Concrete base shall be level prior to setting cleaning system. If required, use grout to assure a level surface.

3.2 CONNECTIONS

A. Maintain manufacturer’s recommended clearances for service and maintenance.

B. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

C. Install piping adjacent to coolers to allow services and maintenance.

D. Connect drain lines to nearest floor sink, or other location as indicated on Drawings.

E. Domestic Water Piping: Comply with applicable requirements in Division 22 Section 22 11 16 “Domestic Water Piping.” Connect to water-level control with shut-off valve and union or flange at each connection.

F. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories.

G. Make final duct connections to evaporative coolers with flexible connectors. Flexible connectors are specified in Division 23 Section 23 33 00 “Duct Accessories.”

H. Install ducts adjacent to evaporative coolers to allow service and maintenance.

I. Electrical System Corrections: Comply with applicable requirements in Division 26 Sections for power wiring, switches, and motor controls.

J. Ground equipment according to Division 26.

3.3 FIELD QUALITY CONTROL

A. Operation Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Remove malfunctioning units, replace with new units, and retest.

B. Test & adjust controls and safeties. Replace damaged & malfunctioning controls and equipment.

C. Shut unit down and reconnect automatic temperature-control operators.

D. Refer to Division 23 Section 23 05 93 “Testing, Adjusting, and Balancing” for testing, adjusting, and balancing procedures.

E. Adjust or replace fan and motor pulleys as required to achieve design airflow.

END OF SECTION

SECTION 23 64 16

CENTRIFUGAL WATER CHILLERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes packaged, water-cooled, electric-motor-driven, centrifugal water chillers with the following features:
   1. Motor controller.
   2. Microprocessor-based controls.

B. See Drawings for specific chiller characteristics, capacity, efficiency, voltage, short circuit current rating, etc.

1.2 ACTION SUBMITTALS

A. Product Data: For each model indicated, provide the following:
   1. Dimensioned prints of water chiller assemblies, including control panels, sections, and elevations, and unit isolation.
   2. Structural support requirements.
   3. Piping roughing-in requirements.
   4. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
   5. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.
   6. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
   7. Performance at AHRI standard conditions and at conditions indicated.
   8. Performance at AHRI standard unloading conditions.
   9. Minimum evaporator flow rate.
   10. Minimum condenser flow rate.
   11. Refrigerant capacity of chiller.
   12. Oil capacity of chiller.
   13. Fluid capacity of evaporator, condenser.
   14. Characteristics of safety relief valves.
   15. Minimum entering condenser-fluid temperature.
   16. Performance at varying capacities with constant design condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in 5 deg F increments.
   17. Force and moment capacity of each piping connection.

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings:

1. Drawings, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved
   a. Structural supports.
   b. Piping roughing-in requirements.
   c. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
   d. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.

B. Manufacturer’s startup service reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

B. Warranties: Special warranties specified in this Section.

1.5 QUALITY ASSURANCE

A. ARI Certification: Signed by manufacturer certifying compliance with requirements in ARI 550/590, "Water Chilling Packages Using the Vapor Compression Cycle."

B. ASHRAE Certification: Signed by manufacturer certifying compliance with ASHRAE 15 for safety code for mechanical refrigeration. Comply with ASHRAE Guideline 3 for refrigerant leaks, recovery, and handling and storage requirements.

C. ASME Compliance: Fabricate and label water chiller heat exchangers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

D. Comply with NFPA 70.

E. Comply with UL 1995.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Ship chillers from the factory fully charged with refrigerant.

B. Ship each chiller with a full charge of refrigerant. Charge each chiller with nitrogen if refrigerant is shipped in containers separate from chiller.

C. Ship each oil-lubricated chiller with a full charge of oil.
   1. Ship oil factory installed in chiller or in containers separate from chiller.

D. Package chiller for shipping in totally enclosed bagging.

1.7 WARRANTY

A. Extended 5-Year Maintenance Agreement: Provide a 5-year extended maintenance agreement covering the period from the date of shipment to 66 months after the ship date. Provide the following each year, unless otherwise indicated:
   1. Seasonal startup and shutdown
   2. Four inspections including – but not limited to – the following:
      a. Operating temperatures and pressures
      b. Operating and safety controls
      c. Purge unit
      d. Starter: Mechanical linkages, start contactors and timers. Dry run starter to ensure proper timing of starting sequence and proper starter operation. Recalibrate starter overloads.
      e. Once per year, make recommendations for the cleaning of each heat exchanger. Technician shall take measurements of small temperature difference across heat exchanger tubes and base the recommendation on this data.
   3. Oil analysis (if applicable) and a refrigerant analysis. Submit results and recommendations to the owner.
   4. Oil filter changes (if applicable)
   5. Eddy current testing of evaporator (baseline and year 5)
   6. Eddy current testing of condenser (baseline, year 3, and year 5)
   7. Vibration analysis (baseline, year 3, and year 5

B. Special Warranty: Warranty shall cover parts and labor and refrigerant required to remedy defects in materials or workmanship for the entire chiller. Perform warranty work with manufacturer’s factory-trained and factory-employed service technician

PART 2 - PRODUCTS *(NOTE: Part 2 shall be developed and tailored for each specific Project)*

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. YORK International Chiller Solutions from Johnson Controls.
   2. Trane Technologies.
   3. Daikin International.

2.2 PACKAGED WATER CHILLERS

A. Description: Factory-assembled and -tested water chiller complete with compressor, evaporator, condenser, controls, interconnecting unit piping and wiring, indicated accessories, and mounting frame.

B. ASHRAE Compliance:
   1. ASHRAE 15 for safety code for mechanical refrigeration.
   2. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.

C. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1.

D. ASME Compliance: Fabricate and label chillers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, as applicable to chiller design. For chillers charged with R-134a refrigerant, include an ASME U-stamp and nameplate certifying compliance.

E. 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.

F. Comply with requirements of Underwriters Laboratories Inc. and include label by a qualified testing agency showing compliance.

G. Operation Following Loss of Normal Power:
   1. Equipment, associated factory- and field-installed controls, and associated electrical equipment and power supply connected to backup power system shall automatically return equipment and associated controls to the operating state occurring immediately before loss of normal power without need for manual intervention by an operator when power is restored either through a backup power source, or through normal power if restored before backup power is brought online.
   2. Refer to Drawings for equipment served by back-up power systems.
   3. Provide means and methods required to satisfy requirement, even if not explicitly indicated.

2.3 COMPRESSORS

A. Description: Variable displacement with gear-or direct-drive, open or hermetically sealed motor.
   1. Casing: Cast iron, precision ground.
   2. Impeller: High strength, cast-aluminum alloy on carbon or forged-steel shaft; dynamically balanced.

B. Capacity Control: Variable Speed Drive plus variable-inlet guide-vane assembly for stable operation that is free of surge, cavitation, or vibration throughout throttling range from 100 to 10 percent of full load.

C. Oil Lubrication System: Positive-displacement submersible pump with heater, oil filter, and sight glass.

D. Refrigerant and Oil: HFC-134a or R-123 with compatible oil unless noted otherwise in schedule on Drawings.

E. Refrigerant Compatibility: Seals, O-rings, motor windings on hermetic compressors, and internal water chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.

2.4 HEAT EXCHANGERS

A. Evaporator:
   1. Description: Shell-and-tube design, ASME labeled.
   2. Shell Material: Carbon steel.
   3. Tube Construction: Individually replaceable, expanded into tube sheets.
      a. Material: Copper.
      b. Minimum Size: 3/4-inch OD, 0.028-inch wall thickness.
      c. Internal Finish: Enhanced.
   4. Water Box: Standard or marine as indicated on drawings, with design working pressure of 150 psig, and having flanged or grooved mechanical-joint coupling water-nozzle connections with a thermistor-type temperature sensor factory installed in each nozzle. Provide vent and drain connections with plugs.

B. Condenser:
   1. Description: Shell-and-tube design, ASME labeled.
   2. Shell Material: Carbon steel.
   3. Tube Construction: Externally enhanced and individually replaceable, expanded into tube sheets.
      a. Material: Copper.
      b. Minimum Size: 3/4-inch OD; 0.028-inch wall thickness.
      c. Internal Finish: Enhanced.
   4. Water Box: Standard or marine as indicated on drawings, with design working pressure of 150 psig, and having flanged or grooved mechanical-joint coupling water-nozzle connections with a thermistor-type temperature sensor factory installed in each nozzle. Provide vent and drain connections with plugs.

2.5 INSULATION

A. Cold Surfaces: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type II, for sheet materials. Field insulate all surfaces which are not insulated at factory and paint to match factory insulation color.

2.6 PAINT

A. Paint: Factory coat all exposed surfaces with enamel primer and finish coat, or baked-on powder paint.

2.7 ACCESSORIES

A. Pressure Relief Devices:

1. Comply with requirements in ASHRAE 15, ASHRAE 147, and applicable portions of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.
2. Select and configure pressure relief devices to protect against corrosion and inadvertent release of refrigerant.
3. Where dual pressure relief devices are installed in series, provide a sensor with indicator between devices to indicate refrigerant release past first device.
4. Rupture Guard: Provide spring loaded reseating type rupture guard on HCFC-123 water chillers with refrigerant recovery system. Size rupture guard per manufacturers written directions and ASHRAE 15.
5. For Chillers Using R-134a: ASME-rated, spring-loaded, pressure relief valve; single- or multiple-reseating type. Pressure relief valve(s) shall be provided for each heat exchanger. Condenser shall have dual valves with one being redundant and configured to allow either valve to be replaced without loss of refrigerant.
6. Size relief vent piping per manufacturers written directions and ASHRAE 15. Provide calculations with chiller submittals.

B. Refrigeration Transfer: Provide service valves and other factory-installed accessories required to facilitate transfer of refrigerant from chiller to a remote refrigerant storage and recycling system. Comply with requirements in ASHRAE 15 and ASHRAE 147

C. Refrigerant Isolation for Chillers Using R-134a:

1. Factory install isolation valves in the compressor discharge line to the condenser and the refrigerant liquid line leaving the condenser to allow for isolation and storage of full refrigerant charge in the chiller condenser shell.
2. Suction side of compressor from evaporator shall have an isolation valve to allow for isolation and storage of full refrigerant charge in the chiller evaporator shell.

D. Purge Systems:

1. On water chiller which utilize HCFC-123 refrigerant, provide a factory mounted, air, water, or refrigerant cooled purge system; with operating controls, piping, elapsed-time meter, and refrigerant service valves to isolate the purge unit from the chilling unit.
2. System shall be of thermal purge design, refrigerant or air cooled, and equipped with a carbon filter that includes an automatic regeneration cycle.
3. Factory wire to chiller's main power supply and system complete with controls, piping, and refrigerant valves to isolate the purge system from the chiller.
4. Construct components of noncorrodible materials.
5. Controls shall interface with chiller control panel to indicate modes of operation, set points, data reports, diagnostics, and alarms.
6. Efficiency of not more than 0.02 lb of refrigerant per pound of air when rated according to AHRI 580.
7. Operation independent of chiller according to ASHRAE 147.

E. Positive Pressure System:
1. For chillers operating at subatmospheric pressures (using R-123 refrigerant), factory install an automatic positive-pressure system.
2. During nonoperational periods, positive-pressure system shall automatically maintain a positive pressure for atmosphere in the refrigerant-pressure vessel of not less than 0.5 psig adjustable up to a pressure that remains within the vessel design pressure limits.
3. System shall be factory wired and include controller, electric heat, pressure transmitter, or switch.

2.8 CONTROLS

A. Control Panel: Stand-alone, microprocessor based, factory-wired to control transformer in starter.

B. Enclosure: Unit-mounted, NEMA 250, Type 1 enclosure, hinged and lockable.

C. Status Display: Multiple-character liquid-crystal display or light-emitting diodes and keypad. Display the following conditions:
1. Date and time.
2. Operating or alarm status.
3. Operating hours.
4. Temperature and pressure operating set points.
5. Entering and leaving temperatures of chilled water and condenser water.
6. Refrigerant pressures in evaporator and condenser.
7. Saturation temperature in evaporator and condenser.
8. Oil temperature and pressure.
9. Percent of maximum motor amperage.
10. Current-limit set point.
11. Number of compressor starts.
12. Purge suction temperature if purge system is provided.
13. Purge elapsed time if purge system is provided.

D. Control Functions:
1. Manual or automatic startup and shutdown time schedule.
2. Leaving chilled-water temperature, and motor load limit.
3. Current limit and demand limit.
4. External water chiller emergency stop.

E. Manually Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
1. Low evaporator pressure or temperature.
2. High condenser pressure.
3. Low chilled-water temperature.

4. Low oil differential pressure.
5. High or low oil pressure.
6. High oil temperature.
7. High compressor-discharge temperature.
8. Loss of chilled or condenser-water flow.
9. Electrical overload.
10. Sensor or detection-circuit fault.
11. Processor communication loss.
12. Starter fault.
13. Extended compressor surge.
14. Excessive air-leakage detection (for water chillers utilizing HCFC-123 refrigerant).
15. Phase failure and undervoltage conditions.

F. Building Automation System Interface: Furnish terminal strip connections for the following:
1. Chiller enable/disable.
2. Leaving chilled water temperature setpoint adjustment (0-10 VDC 4-20mA).
3. External demand limit setpoint adjustment (0-10 VC 4-20mA).
4. General chiller alarm contact closure.

2.9 MOTORS

A. Comply with requirements in Division 23 Section 23 05 13 "Common Motor Requirements for HVAC Equipment."
1. Open-drive motors shall have flanged or flexible coupling suitable for direct connection to compressor. Provide OSHA compliant guard over coupling.

2.10 COMPRESSOR MOTOR STARTER: VARIABLE SPEED DRIVE

A. General: Variable Speed Drive (VSD) compressor motor starter to start motor and control motor speed by controlling the frequency and voltage of the electrical power supplied to the motor.

B. Drive Type: Pulse width modulated (PWM) utilizing insulated gate bipolar transistors (IGBTs)

C. Control Logic: Independently control motor speed and pre rotation vane (PRV) position for optimum efficiency and operational stability. Base motor speed and PRV position on a minimum of 4 inputs: leaving chilled water temperature, return chilled water temperature, evaporator refrigerant pressure, condenser refrigerant pressure; Verify motor speed and PRV position and also use as inputs to the control logic.

D. Power Factor: At loads and speeds, provide a minimum of a .95 power factor; or a .98 power factor with active harmonic filtration.

E. Enclosure: NEMA 250 Type-1; hinged access door with door interlock; lock and keys; padlockable.

F. Packaging: Factory mounted on chiller, piped to cooling circuit; wired to control panel, compressor motor, oil pump and purge; entire package (including active harmonic filter) shall be UL listed

G. Cooling: Cool drive and harmonic attenuation components and internal ambient air via fluid-cooled, closed loop; starter components accessible for service and replacement without opening the chiller's main refrigerant circuit.

H. Factory Run Test: Perform an electrical and mechanical run test of VSD starter prior to shipment to verify proper wiring and phasing.

I. Factory Settings: Set starting design current and current overload settings prior to shipment

J. Harmonic Distortion: Provide a drive and chiller system with integrated harmonics attenuation circuitry mounted inside the starter cabinet. System must generate harmonic distortion levels less than the following, measured at the input side of the drive:
  1. Current: 29% maximum current total demand distortion

K. Inrush Amperage: limited to the design full load amperage of the chiller.

L. Protective Devices: Provide the following, as a minimum:
  1. Electronic current-sensing overloads (1 per phase): with indicating message on the control panel and reset button; shut down chiller upon detection of operating current exceeding 105% full load amperage.
  2. High instantaneous current overload: with indicating message on the control panel and reset button; shut down chiller upon detection of starting current exceeding 115% of design inrush starting current for 1 second.
  3. Phase rotation insensitivity.
  4. Single phase failure protection circuit with indicating light: shut unit down if power loss occurs in phase at startup.
  5. High temperature safety protection system on IGBTs with indicating light and reset button; via thermistors embedded on IGBT heat sinks: shut unit down if IGBT temperature exceeds acceptable limits.
  6. Power fault protection for momentary power interruptions: interrupt power to the compressor motor within 4 line cycles upon detection of power interruptions longer than ¾ of a line cycle.
  7. High and low line voltage protection.

M. Features: Factory mount and wire the following as a minimum:
  1. Control Transformer: 115volt, sized to power control panel and unit controls
  2. Electrical Lugs: Tin plated, sized to accept the copper power lines required by the chiller.

3. Single Point Power: From electrical lugs at starter, power powered devices on the chiller including control panel, control devices, line reactor circuitry, active harmonic filter, oil pump and refrigerant purge
4. Circuit-breaker disconnect: door interlocked; ground fault protection; minimum 65,000A short circuit withstand capacity per UL 508.

N. Control Panel Readouts: Display on the control panel and provide to BAS via communication port the following as a minimum:
1. Output frequency.
2. Output voltage.
3. Three phase current.
4. Input power (kW).
5. Energy consumption (kWh).
6. Elapsed running time.

2.11 SOURCE QUALITY CONTROL

A. Factory test and rate water chillers, before shipping, according to ARI 550/590, "Water Chilling Packages Using the Vapor Compression Cycle." Stamp with ARI label.

B. Factory test heat exchangers hydrostatically at 1.50 times the design pressure.

C. Factory test and inspect evaporator and water cooled-condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Stamp with ASME label.

D. Factory test and inspect water boxes at 150 percent of working pressure.

E. Rate sound power level according to ARI 575 procedure.

F. Heat Exchangers (evaporator and condenser):
1. Design and test in full conformance to the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.
2. Hydrostatically test evaporator and condenser refrigerant side at 1.3 times design working pressure AFTER tubing using LIQUID REFRIGERANT.

G. Compressor Components:
1. Leak tested at design working pressure using air under water.
2. Hydrostatic strength test at 1.5 times design working pressure.
3. To ensure UL label qualification, manufacturer shall perform a hydrostatic strength test at 3 times design working pressure every year on the compressor castings.
4. Statically and dynamically balance each impeller.
5. Overspeed test each impeller at 120% of its maximum design RPM.

H. Motor:
1. Balance rotor in accordance with NEMA MG1.

2. High-potential test stator for dielectric strength for 1 second per NEMA MG1 and the following formula: 1.2 * (2 * RATED VOLTAGE + 1000).
3. 400 hp motors and larger: Megohm meter reading after high potential test.
4. No-load readings of current and speed at design voltage and frequency per NEMA standard MG1, including current input at rated frequency with rotor locked.

I. Chiller air run test for 30 minutes:
   1. Measure current and voltage across each phase
   2. Stroke prerotation vane actuator and cycle vanes from fully closed to fully open
   3. Operate control panel, test functionality and log instrument readings at 10-minute intervals.
   4. Operate oil pump motor and search lubrication system for leaks.
   5. Check compressor oil pressure.
   6. Vibration readings on driveline assembly in the horizontal, vertical and axial planes.
   7. After the test, remove and replace oil filter.

J. Chiller Leak Integrity Testing: Pressurize entire system to design working pressure. Leak test using soap and water. Repair leaks and repeat test until leak tight

K. Vacuum Hold Testing: Evacuate system to 500 microns and hold for one hour. Ensure that pressure does not rise more than 150 microns during the hour. Repair and repeat until passes.

2.12 OPTIONS

A. Refrigerant Isolation Valves: Two butterfly valves, one on the compressor discharge line and one on the liquid line.

B. Insulation Package: Factory insulate evaporator, end sheets, suction line, liquid line and other cold surfaces with 3/4” closed-cell neoprene foam insulation. Adhere with vapor-proof cement. Water boxes and nozzles shall be field insulated with removable covers over bolts.

C. Flow Sensors, Thermal Type: Factory installed in chilled and condenser water nozzles and factory wired to chiller control panel.

D. Provide sacrificial anodes at heat exchangers.

E. Control System Interface: DDC type:
   1. Provide the following as a minimum:
      a. Export system operating data.
      b. Accept setpoint adjustments for chilled water setpoint and demand limit.
      c. RS-232 communication.
      d. Field commissioning assistance by manufacturer’s technician.

2.13 CURRENT TESTING

A. Heat exchanger tube testing shall be performed at the chiller manufacturing facility to ensure tube quality and longevity. Prepare and furnish test report to include the following as a minimum.
   1. List of test equipment used and equipment settings.
   2. Test data reports and accompanying strip charts of calibrations and tubes with significant defect and typical indications.
   3. Statistical summary of defect indications.
   4. Recommendations concerning tube condition, tube replacement, tube removal for evaluation and future frequency of testing.
   5. Approval by an ASNT Level III eddy current technician.

PART 3 - EXECUTION

3.1 WATER CHILLER INSTALLATION

A. Install water chillers on cast in place isolated concrete base. Concrete base is specified in Division 23 Section 23 05 15 "Common Work Results for HVAC," and concrete materials and installation requirements are specified in Division 03.

B. Concrete Bases: Anchor chiller mounting frame to concrete base.
   1. 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 concrete base.
   2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   4. Install anchor bolts to elevations required for proper attachment to supported equipment.
   5. Cast-in-place concrete materials and placement requirements are specified in Division 03.

C. Vibration Isolation: Neoprene pads furnished by the water chiller manufacturer with a minimum deflection of 0.25 inch. Vibration isolation devices and installation requirements are specified in Division 23 Section 23 05 48 "Vibration Controls for HVAC Piping and Equipment."

D. Maintain manufacturer's recommended clearances for service and maintenance.

E. Charge water chiller with refrigerant if not factory charged.

F. Install separate devices furnished by manufacturer.

3.2 CONNECTIONS

A. Chilled and condenser-water piping installation requirements are specified in Division 23 Section 23 21 13 "Hydronic Piping." Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to water chillers to allow service and maintenance.

C. Evaporator Connections: Connect inlet to evaporator with controller-bulb well, shutoff valve, thermometer, and pressure gage. Connect outlet to evaporator with throttling valve, flow switch, thermometer, pressure gage, and drain line with shutoff valve.

D. Condenser Connections: Connect inlet to condenser with shutoff valve, thermometer, and pressure gage. Connect outlet to condenser with throttling valve, thermometer, pressure gauge, flow switch, and drain line with shutoff valve.

E. Refrigerant Pressure Relief Valve Connections: Extend vent piping to the outside without valves or restrictions.

F. Ground water chillers according to Division 26.

G. Connect wiring according to Division 26.

3.3 STARTUP SERVICE

A. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.

B. Engage a factory-authorized service representative to complete the installation and startup checks according to the manufacturer's written instructions and perform the following:

1. Verify that refrigerant charge is sufficient and water chiller has been leak tested.
2. Verify that pumps are installed and functional.
3. Verify that thermometers and gages are installed.
4. Operate water chiller for run-in period according to manufacturer's written instructions.
5. Check bearing lubrication and oil levels.
6. Verify that refrigerant pressure relief is vented outside.
7. Verify proper motor rotation.
8. Verify static deflection of vibration isolators, including during startup and shutdown.
9. Record performance of chilled and condenser-water flow and low-temperature interlocks.
10. Verify and record performance of water chiller protection devices.
11. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

C. Prepare a written startup report that records results of tests and inspections.

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

3.4 DEMONSTRATION

A. Engage a factory-authorized service representative to train the Owner’s maintenance personnel adjust, operate and maintain the chiller. Provide not less than 4 hours of training.

END OF SECTION

SECTION 23 65 00

COOLING TOWERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Open-circuit, induced-draft, cooling towers.
   2. Basin sweeper cleaning and filtration system.

1.2 ACTION SUBMITTALS

A. Product Data:
   1. For each cooling tower model indicated, provide rated capacities at design conditions, pressure drop, fan performance data, physical dimensions, required clearances, weights, sizes and locations of field connections, electrical requirements, and accessories including the following:
      a. Assembled unit dimensions.
      b. Weight and load distribution.
      c. Required clearances for maintenance and operation.
      d. Sizes and locations of piping and wiring connections.
      e. Wiring Diagrams: For power, signal, and control wiring. Differentiate between manufacturer installed and field installed wiring
      f. Maximum flow rate.
      g. Minimum flow rate.
      h. Pressure required at cooling tower supply piping connections.
      i. Pressure required at basin heater supply piping connections.
      j. Pressure required at collection basin sweeper supply piping connections.
      k. Drift loss as percent of design flow rate.
      l. Volume of water in suspension for purposes of sizing remote storage.
      m. Sound:
      n. Sound pressure levels for operation with fan off, fan at minimum speed, and design speed. If sound requirements are indicated at a specific distance, submit performance using same distance for comparative analysis.
      o. Sound power levels in eight octave bands for operation with fans off, fans at minimum speed, and design speed.
      p. Fan airflow at design conditions, brake horsepower, and drive losses (indicated in horsepower and percentage of brake horsepower).
      q. Fan motor electrical characteristics, including but not limited to, speed, voltage, phase hertz, amperage, efficiency, and power factor at 100, 75, 50, and 25 percent of nameplate horsepower.
      r. Electrical power requirements for each cooling tower component requiring power.

2. For basin cleaning and filtration system indicated, provide rated capacities at design conditions, pressure drops, performance data, drawings, physical dimensions, required clearances, weights, sizes and locations of field connections, electrical requirements, and accessories.

B. Shop Drawings: Manufacturer's drawings of assembled cooling towers, control panels, sections, and elevations. Include the following:

1. Assembled unit dimensions.
2. Diagram showing each separate piece requiring field assembly.
3. Shipped sub-assembly dimensions and weights for field assembly.
4. Assembled unit weight without water.
5. Operating weight and load distribution.
6. Unit vibration isolation and seismic controls.
7. Required clearances for maintenance and operation.
8. Sizes and dimensioned locations of piping and wiring connections.
9. Diagrams for power, signal, and control wiring.

C. Field quality control reports.

D. Manufacturer’s startup service reports.

1.3 INFORMATIONAL SUBMITTALS

A. Seismic Qualification Certificates: For cooling towers, accessories, and components, from manufacturers.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

B. Warranties: Special warranties specified in this Section.

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. ASHRAE/IESNA 90.1 for energy efficiency.

C. ASME Compliance: Fabricate and label heat-exchanger coils to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

D. CTI Certification: Cooling tower thermal performance according to CTI STD 201, "Certification Standard for Commercial Water-Cooling Towers Thermal Performance."

1.6 DELIVERY, STORAGE, AND HANDLING

A. Coordinate requirements for multi-piece assembly for shipment. Limit the number of separate pieces for field installation to as few as possible.

B. If factory assembly of multiple pieces is required for testing or other reasons, disassemble cooling tower into major assemblies as required by installation before packaging for shipment.

C. Clearly label each package with a unique designation and include assembly instructions for each complete cooling tower.

1.7 WARRANTY

A. Special Warranty: Unit shall have a comprehensive five (5) year warranty against defects in materials and workmanship from substantial completion in which manufacturer agrees to repair or replace the following components of cooling towers that fail in materials or workmanship within specified warranty period:
   1. Fan assembly including supports, fan, drive, and motor.
   2. Fan shafts, bearings and sleeves.
   3. Gearboxes
   4. Tube bundle
   5. External circuit circulating pump

PART 2 - PRODUCTS *(NOTE: Part 2 shall be developed and tailored for each specific Project)*

2.1 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Cooling towers shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
   1. The term "withstand" means "the unit will remain in place without separation of parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.

2.2 OPEN CIRCUIT, INDUCED DRAFT, COOLING TOWERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings or comparable product by one of the following:
   1. Baltimore Aircoil Company.
   2. Evapco Inc.

3. Marley Cooling Technologies, an SPX Corporation.

B. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.

C. Cooling tower designed to resist wind load of 30 lbf/sq. ft.

D. Casing and Frame:
   1. Casing and Frame Material: Type 304 Stainless steel. "Series 300" stainless steel will not be acceptable as equivalent to Type 304 Stainless Steel.
   2. Fasteners: Stainless steel to match casing and frame.
   3. Joints and Seams: Sealed watertight.
   4. Welded Connections: Continuous and watertight.

E. Collection Basin:
   1. Material: Type 304 Stainless steel. "Series 300" stainless steel will not be acceptable as equivalent to Type 304 Stainless Steel.
   2. Removable stainless-steel strainer with openings smaller than nozzle orifices.
   3. Overflow and drain connections.
   4. Makeup water connection.
   5. Outlet Connection: ASME B16.5, Class 150 flange.
   6. Equalizer connection for field-installed equalizer piping location and size as indicated on drawings (for multiple-cooling-tower systems).

F. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
   1. Enclosures: NEMA 250, Type 4X.
   2. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide control of water makeup valve, low- and high-level alarms.
   3. Electrode Probes: Stainless steel.
   4. Water Stilling Chamber: Corrosion-resistant material.
   5. Solenoid Valve: Slow closing with stainless-steel body, controlled and powered through level controller in response to water-level set point.
   6. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

G. Fill:
   1. Materials: PVC, with maximum flame-spread index of 5 according to ASTM E 84.
   2. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
   3. Fill Material Operating Temperature: Suitable for entering-water temperatures up through 120 deg F.

H. Drift Eliminator:
   1. Material: PVC; with maximum flame-spread index of 5 according to ASTM E 84.

2. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
3. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.

I. Air Intake Louvers:
   1. Material: FRP, PVC, or stainless steel as scheduled.
   2. UV Treatment: Inhibitors to protect FRP or PVC louvers against damage caused by UV radiation.
   3. Louver Blades: Arranged to uniformly direct air into cooling tower, to block sunlight in basin, to minimize air resistance, and to prevent water from splashing out of tower during modes of operation including operation with fans off.

J. Axial Fan: Balanced at the factory after assembly.
   1. Blade Material: Aluminum.
   2. Hub Material: Aluminum.
   3. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
   4. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F. Bearings designed for an L-10 life of 100,000 hours.
   5. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

K. Gear Drive: Where indicated on Drawings. Right angle, reduced speed, and designed for cooling tower applications according to CTI STD 111. Motor and gear drive shall be aligned before shipment.
   1. Gear Drive and Coupling Service Factor: 2.0 based on motor nameplate horsepower.
   2. Housing: Cast iron, with epoxy or polyurethane finish, beveled high-strength steel gears continuously bathed in oil, and with lubrication to other internal parts at operating speeds.
   3. Mounting: Directly mounted to fan hub and connected to motor so motor shaft is in horizontal position.
   4. Operation: Able to operate both forward and in reverse.
   5. Drive Shaft Material: Corrosion resistant composite material or Stainless steel, and fitted with flexible couplings on both ends. Provide exposed shaft and couplings with guards according to OSHA regulations.
   6. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized-steel piping. Provide installation with oil-level sight glass.

L. Direct Drive: Where indicated on Drawings. The motor will be directly connected to the fan shaft within the airstream, eliminating the need for couplings, right-angle gears, belts, or sheaves.
   1. Quality Assurance:
      a. Tower thermal performance must be certified per CTI STD-201.
      b. Manufactured under ISO 9001 approved quality assurance program.

c. Vibration tested per ICC-ES AC 156; must meet local Sds requirement but cannot be less than 0.50.
d. Analyzed for structural resonance per CTI STD-163; maximum resonance must not exceed 0.36 in/sec.
e. Tested and certified to operate continuously at 104°F ambient wet bulb temperature.
f. Compatible VFD supplied by tower manufacturer; see VFD specification for details.

2. General:
   a. CSA Label and CE mark for safety compliance.
   b. Totally Enclosed Air Over (TEAO) IP56 rating.
   c. Interior permanent magnet rotor construction; synchronous design; magnets enclosed inside the rotor lamination; magnets with high temperature grade capable of 200°C conditions without loss of magnetization.
   d. Compliance with NEMA MG 1 part 31 standards for definite-purpose inverter-fed motors suitable for 2000 volt peak at 10,000 volt per microsecond.
3. Components:
   a. Bearing isolator (seal) on motor shaft provided with shaft grounding device, utilizing two carbon grounding brushes to eliminate bearing currents.
   b. Salient pole permanent magnet design rotor resulting in no I^2R losses.
   c. Stator consisting of low-loss C5a coated electrical steel.
   d. Integral stator cooling fins, not a shaft mounted fan, for controlling rotor and stator temperatures during operation.
   e. Class H insulation system rated at 1850 Volts peak, and thermally-rated wire when tested per ASTM D-2307 for 600,000 hours extrapolated life at 155°C minimum.
   f. Shaft sealed by three O-rings, with two conductive O-rings to properly ground the bearing, eliminating damaging currents in the bearings.
   g. Oversized conduit box with provisions for grounding inside.
   h. Integral condensate drain system.
   i. Three normally closed thermostats, one per phase.
   j. Open ball bearings with a minimum L10 life of 100,000 hours.
   k. Bearings sized to handle unbalanced loads based on an ISO Balance Grade of 6.3.
   l. Re-greaseable bearing system including stainless steel inlet fitting and grease drain provided with square stainless-steel square head pipe plugs.

M. Fan Motor:
1. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section 23 05 13 "Common Motor Requirements for HVAC Equipment" and not indicated below.
2. Motor Enclosure: Totally enclosed.
3. Energy Efficiency: NEMA Premium Efficient.
4. Service Factor: 1.15.
5. Insulation: Class H.

6. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."

N. Motor Davit with Base:
   1. Unit shall be provided with mechanical external motor davit assembly which facilitates in removal of larger fan section components. Davit arm shall be constructed of aluminum and base shall be galvanized steel.

O. Fan Discharge Stack: Material shall match casing, manufacturer's standard velocity recovery design.
   1. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.

P. Vibration Switch: For each fan drive.
   1. Enclosure: NEMA 250, Type 4X.
   2. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
   3. Provide switch with manual-reset button for field connection to a BMS and hardwired connection to fan motor electrical circuit.
   4. Switch shall, on sensing excessive vibration, signal an alarm through the BMS and shut down the fan.

Q. Controls: Comply with requirements in Division 23 Section 23 09 23 "Instrumentation and Controls for HVAC."

R. Personnel Access Components:
   1. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.
   2. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel as scheduled, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
   3. Provide OSHA approved aluminum or stainless steel as scheduled fan deck hand railing around top of each cooling tower complete with kneerail and toeboard, to safeguard personnel while accessing components located on top of cooling tower. Comply with 29 CFR 1910.23.
   4. External Platforms with Handrails: Provide Aluminum, FRP, or galvanized-steel as scheduled bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
   5. Handrail: Aluminum or stainless steel as scheduled complete with kneerail and toeboard, around top of cooling tower to safeguard personnel while accessing components located on top of cooling tower. Comply with 29 CFR 1910.23.

6. Internal Platforms: Aluminum, or galvanized-steel as scheduled bar grating.
   a. Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that parts are above the high water level of the collection basin.
   b. Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.
7. Ladder and platform locations to be determined during the shop drawing phase. Final location modifications shall be at no price change to Owner.

2.3 BASIN SWEEPER CLEANING AND FILTRATION SYSTEM

A. The cold water basin shall be equipped with PVC sweeper piping with plastic eductor nozzles. The piping should create a grid under the fill and force dirt and debris to the depressed section of the collection basin.

B. Sweeper piping shall be Schedule 80 PVC with nozzles pointed inward from both intake faces. The separator shall pull from the center depressed section of the cold water basin.

C. Locations of outlets to be determined in the shop drawing submittal. Location of openings shall be at no cost to Owner.

D. Nozzles shall be sized to handle minimum 1 gpm per square foot of cold water basin and placed at a maximum of 24” on center.

E. The system shall include a skid mounted separator, filter assembly, circulation pump, motor, and controls.

F. Manufacturer: Lakos TC Series or approved equal.

2.4 SOURCE QUALITY CONTROL

A. Factory pressure test heat exchangers after fabrication and prove to be free of leaks.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install cooling towers and other equipment on support structure indicated.

B. Equipment Mounting: Install cooling tower and other equipment on concrete base using elastomeric pads in the absence of instructions on the Drawings. Comply with requirements for concrete base in Division 03. Comply with requirements for vibration isolation devices specified in Division 23 Section 23 05 48 "Vibration and Seismic Controls for HVAC Piping and Equipment."
   1. Minimum Deflection: As indicated on Drawings.
   2. Provide stainless-steel plate to equally distribute weight over elastomeric pad.

3. 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 concrete base.
4. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
5. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

C. Install anchor bolts to elevations required for proper attachment to supported equipment.

D. Maintain manufacturer's recommended clearances for service and maintenance.

E. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

3.2 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to cooling towers to allow service and maintenance.

C. Install flexible pipe connectors at pipe connections of cooling towers mounted on vibration isolators.

D. Provide drain piping with valve at cooling tower drain connections and at low points in piping.

E. Connect cooling tower overflows and drains, and piping drains to nearest floor sink or other location as indicated on Drawings.

F. Domestic Water Piping: Comply with applicable requirements in Division 22 Section 22 11 16 "Domestic Water Piping." Connect to water-level control with shutoff valve and union, flange, or mechanical coupling at each connection.

G. Condenser-Water Supply and Return Piping: Comply with applicable requirements in Division 22 Section 23 21 13 "Hydronic Piping." Connect to entering cooling tower connections with shutoff valve, balancing or flow control valve, thermometer, plugged tee with pressure gage, flow meter, and drain connection with valve. Connect to leaving cooling tower connection with shutoff valve. Make connections to cooling tower with a union or flange.

H. Equalizer Piping: Piping requirements to match supply and return piping. Connect an equalizer pipe, full size of cooling tower connection, between tower cells. Connect to cooling tower with shutoff valve.

I. Provide circulation and drain piping for the basin cleaning and filtration system as indicated on the Drawings.

3.3 FIELD QUALITY CONTROL

A. Perform tests and inspections.
   1. Manufacturer's Field Service: Where field-assembly of major sections is required engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to perform startup service.

3.4 STARTUP SERVICE

A. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.

B. Obtain performance data from manufacturer.
   1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
      a. Clean entire unit including basins.
      b. Verify that accessories are properly installed.
      c. Verify clearances for airflow and for cooling tower servicing.
      d. Check for vibration isolation and structural support.
      e. Lubricate bearings.
      f. Verify fan rotation for correct direction and for vibration or binding and correct problems.
      g. Adjust belts to proper alignment and tension.
      h. Verify proper oil level in gear-drive housing. Fill with oil to proper level.
      i. Operate variable-speed fans through entire operating range and check for harmonic vibration imbalance. Set motor controller to skip speeds resulting in abnormal vibration.
      j. Check vibration switch setting. Verify operation.
      k. Verify water level in tower basin. Fill to proper startup level. Check makeup water-level control and valve.
      l. l. Verify operation of basin heater and control.
      m. Verify that cooling tower air discharge is not recirculating air into tower or HVAC air intakes. Recommend corrective action.
      n. Replace defective and malfunctioning units.

C. Start cooling tower and associated water pumps. Follow manufacturer's written starting procedures.

D. Start the basin cleaning and filtration system in accordance with the manufacturer’s written instructions.

E. Prepare a written startup report that records the results of tests and inspections.

3.5 ADJUSTING

A. Set and balance water flow to each tower inlet.

B. Adjust water-level control for proper operating level.

3.6 TRAINING

A. Train Owner's maintenance personnel to adjust, operate, and maintain cooling towers.

END OF SECTION

SECTION 23 73 13

INDOOR SEMI-CUSTOM AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Packaged, indoor, central-station air-handling units with the following components and accessories:
      a. Indoor Custom Fan Array Air Handling Units.
      b. Supply and Return Fans.
      c. Economizer outdoor- and return-air damper section.
      d. Factory Mounted VFD.
      e. Integral controls.

1.2 DEFINITIONS

A. Outdoor-Air "Outdoor air" is defined as the air outside the building or taken from outdoors and not previously circulated through the system.

B. AHU: Indoor Air Handling unit. As used in this Section, this abbreviation means custom indoor, central-station air-handling units.

C. Supply-Air Fan: The fan providing supply-air to conditioned space. "Supply air" is defined as the air entering a space from air-conditioning, heating, or ventilating apparatus.

D. VVT: Variable-air volume and temperature.

1.3 ACTION SUBMITTALS

A. Product Data: For each product indicated. Include the following:
   1. Indicate dimensions, weights, capacities, and ratings.
   2. Fan performance to include fan curves.
   3. Motor electrical characteristics to include motor technical data sheets.
   4. Coil capacities to include performance printouts with pressure drops (water & air),
   5. Vibration isolation.
   6. Filter data
   7. Include pressure drops, gages, and finishes.

B. Shop Drawings: Indicate assembly weights, unit dimensions, required clearances, construction details, shipping splits, maintenance clearances and field connection details.

C. Wiring Diagrams: Power, signal, and control wiring.

D. Samples for Initial Selection: For metal panel indicated with factory-applied finishes.

1.4 INFORMATIONAL SUBMITTALS

A. Manufacturer's startup service reports.

1.5 CLOSEOUT SUBMITTALS

A. Submit installation, start-up, and Operation & Maintenance Data.
   1. Include instructions for rigging, lifting, bearing lubrication, filter replacement, motor and drive replacement, and wiring diagram.
   2. Include a recommended spare parts list customized to each unit complete with appropriate tag number, serial and / or part numbers along with a description to clearly identify the items.

B. Special warranty.

1.6 QUALITY ASSURANCE

A. ASHRAE Compliance:
   1. Comply with ASHRAE 15 for refrigerant system safety.
   2. Comply with ASHRAE 33 for methods of testing cooling and heating coils.
   3. Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
   4. Applicable requirements in ASHRAE/I ESNA 90.1, Section 6 -"Heating, Ventilating, and Air-Conditioning."

B. Codes and Standards: Comply with requirements of the following:
   1. AMCA 99 – Standards Handbook
   2. AMCA 210 – Laboratory methods of testing fans for rating purposes. Unit to bear AMCA Certified Rating Seal.
   3. AMCA 300 – test code for sound rating air moving devices.
   4. AMCA 310
   5. AMCA 500
   6. Units to bear AMCA certified sound rating.
   7. ANSI/AFBMA 9 Load rating and fatigue life for ball bearings.
   8. ANSI/UL 900 test performance of air filter units.
   9. ARI 410 for coils.
   10. NFPA Compliance: Comply with NFPA 90A and NFPA 908.

C. UL Compliance: Comply with UL 1995.

D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.7 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

B. Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

1.8 DELIVERY, STORAGE & HANDLING

A. Ship units with all openings securely covered with wood and / or nylon reinforced plastic wrap and to be watertight and securely strapped down on an open flatbed truck.

B. Stored units in a clean dry area and protected from the weather and construction traffic. Carefully follow manufacturers’ storage instructions if installation does not immediately follow arrival at the job site.

C. Follow manufacturers rigging guidelines for movement and installation of equipment.

1.9 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to replace components of AHU’s that fail in materials or workmanship within specified warranty period.

B. Warranty Period for Control Boards: Manufacturer's standard, but not less than three years from date of Substantial Completion.

1. Unit manufacturer to warrant its product to be free of defects in materials and workmanship for a period of 24 months from date of Substantial Completion and 3 year warranty on fans and motors, to include all labor and rigging.
2. Equipment found to be defective should be replaced or repaired to include all parts and labor.
3. Component parts that require periodic replacement due to normal wear such as filters, fan belts, etc. are not covered by the warranty.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Huntair, a CES Group Brand
2. Temtrol

3. Trane
4. York/JCI

2.2 AIR HANDLING UNITS, GENERAL

A. Unit shall be completely factory assembled and tested prior to shipment and shall have the approval of one of the following agencies: Underwriters' Laboratories (UL) or Electrical Testing Laboratories (ETL). The air handler shall bear an appropriate label certifying that the unit has been designed and manufactured in strict accordance with the UL 995 Standard for air handling equipment. If the manufacturer cannot provide an ETL/UL sticker on the air handler, it will be the sole responsibility of the contractor to arrange for local ETL or UL approval and labeling.

B. The Unit Electrical Panel(s) shall be built in strict accordance to NEC Standards and shall bear an appropriate label certifying compliance with UL Standard 508A.

C. Air handling equipment manufacturer shall provide single source responsibility for all components for the unit whether specifically manufactured by the unit manufacturer or obtained outside and installed in the equipment.

2.3 CASING FABRICATION

A. General: Formed and reinforced double-wall insulated panels, fabricated to allow removal for access to internal parts and components, with joints between sections sealed.

B. Casing Construction:
   1. Walls and roof to be (3") "Double Wall" construction as indicated in the specification for each section of the unit.
   2. Cabinet is a minimum 16-gauge A60 galvanized outer panel and a minimum 20-gauge G90 galvanized, inner liner for double walls.
   3. Panels to be of standing seam construction with seams turned outward to provide a smooth flush interior.
   4. Panels to be screwed or bolted together on maximum 8" centers with minimum 5/16" zinc plated screws or bolts sealed with a continuous bead of 3M540 caulking applied between the matching panel seams prior to assembly, and with a final bead following assembly on both the exterior and interior panel seams to produce an air tight unit.
   5. Wall to base skin and wall to roof panel seams shall be continuously caulked to ensure leak-proof integrity of the unit housing.
   6. AHU unit housing shall be constructed to prevent conditioned air bypass or mitigation through unit walls, roof and floor around any interior partition or component blank-off walls such as for filters, coils or fan bulkheads.

C. Floor: 0.125" thick steel tread plate floor material with polyurethane foam insulation and 20ga. G90 galvanized base under liner.

D. Insulation: Wall and ceiling panels to be insulated as follows:
   1. Solid Liner: Fiberglass insulation with a thermal conductivity (k) of .26 $Btu{\cdot}in/(hr{\cdot}ft2{\cdot}°F)$ @ 75 °F mean temperature.
   2. Perforated Liner in Supply fan and discharge section: Fiberglass mat-faced insulation with a thermal conductivity (k) of .23 $Btu{\cdot}in/(hr{\cdot}ft2{\cdot}°F)$ @ 75 °F mean temperature.
   3. Interior Liners: to be minimum 20-gauge G90 solid (perforated in Supply fan and discharge section) metal throughout the unit for the walls and roof. Include finish bead of caulking applied between the liner and the interior panel seams to completely seal the panel.

E. Stiffeners of angle steel shall be supplied as required to maintain a casing deflection criteria of 1/100 at 1.5 times the working pressure.

F. Condensate Drain Pans: Formed sections of stainless-steel sheet, a minimum of 2 inches deep, and complying with ASHRAE 62.1.

G. Drain Pans:
   1. Shall be composite plastic or 304 Stainless Steel double-wall construction with solid welded seams for complete water capture and containment.
   2. Pans shall be provided under each horizontal row of cooling coils and shall extend a minimum 12” past the leaving face of the coil in direction of airflow.
   3. Headers and return bends shall be located over the drain pan for collection of all condensate forming on headers and return bends.
   4. Coils shall be easily removable without cutting or removing any portion of the drain pan.
   5. Pans shall be insulated between the liner and the main pan.
   6. Pans shall be IAQ Double Sloping to a single drain.
   7. Drain connection shall be a minimum 1-1/4” diameter MIPS thread extending out through the channel base where indicated on the drawings.
   8. Pans shall be provided for cooling coils, outside air intakes and under other components as required.

2.4 ACCESS DOORS

A. Access doors shall be double wall construction with G-90 galvanized interior panel.

B. Door jamb and frame shall be constructed of extruded aluminum with continuously welded corners for rigidity.

C. Door panels shall be insulated with expandable urethane foam insulation completely encapsulated and sealed between the door panels and frame.

D. Provide doors located and sized to allow for routine maintenance including motor replacement and filter replacement, electrical components and any other sections or components requiring access or maintenance.

E. Provide test ports in all doors into air tunnel.

F. Doors shall be provided with a minimum (2) dual acting heavy duty composite latches through 48” high, (3) latches through 72” high.

G. Latches shall be operable from both the interior and exterior of the unit.

H. Door hinge shall be Stainless Steel heavy duty self-aligning.

I. Door shall be sealed with continuous hollow closed cell foam gasket.

J. Doors to be provided with a dual high performance closed cell replaceable EPDM Sponge Rubber Seal around the entire perimeter of the door / frame.

K. Doors shall open against static pressure.

L. Doors used to access rotating equipment shall be provided with an OSHA approved safety latching mechanism and shall also have a highly visible, permanently fixed, caution sign on the exterior of the door.

M. Doors with access to moving parts must meet current UL mechanical protection guidelines.

N. Standard door size shall be 24” wide by 60” high unless restricted by height or section width.

O. Doors shall be provided with double pane wire reinforced glass viewing windows as called out for on the unit drawings in the specifications.

P. Minimum window size to be 9” x 9” with 12” x 12” provided door size permitting.

2.5 BASES

A. Unit bases shall be constructed from structural steel channel iron or tubing around the entire perimeter of the unit and provided with intermediate structural tubing, channel and angle iron as required to support all internal components. All tubing, channel and angle joints shall be solid welded. Bolted or formed channel bases are not acceptable.

B. Base shall be provided with removable lifting lugs minimum, properly located to assure uniform loading. Maximum spacing between lifting lugs shall be 120”.

C. Units to be structurally designed to set on structural steel (supporting perimeter and across demounts).

D. Large openings (greater than one square foot) in the floor, including dampers openings, shall be covered with a removable powder coated heavy gage steel grating bolted in place suitable for walking on which will prevent any personnel and large objects from falling through into the space below. Grating shall be capable of supporting minimum 300 pounds.

2.6 UNIT FINISHES

A. Exterior wall, roof, and the base structure and the interior floor, grating over floor openings, electrical panels, and inlet cones on the fans shall be powder coated with a lead- and cadmium-free polyester TGIC coating.

B. The interior floor, grating over floor openings, electrical panels, and inlet cones on the fans are to be individually coated & baked following shearing, notching, punching, & forming to provide 100% powder coverage over the entire finished piece to include the interior, exterior, and all metal edges.

C. The coating process is to be completed prior to assembly of the unit to ensure all joined surfaces are covered. Spray or brush applied coatings on the exterior of the cabinet only are not acceptable.

D. Powder Paint to have passed Salt Spray Resistance Test ASTM B 117-90 Minimum 1,000 Hours, Impact Test ASTM D 2794-90 up to 160 lbs and Humidity Resistance Test ASTM D 2247-87 Minimum 1000-hour test w/ maximum blister 1/16 in/1 mm.

   1. Color: As selected by Architect / Owner from manufacturer’s complete line.

2.7 FANS

A. Fans shall be aluminum airfoil, Class III, direct drive arrangement and shall be individually housed. Fans shall be certified by AMCA for performance. Fan shall be housed in a “cell”.

B. The quantity of supply and return fans indicated on the schedule is the minimum and the motor horsepowers scheduled are the maximum.

C. Fan housing or “cell” shall be constructed of aluminum or stainless steel with perforated inner liner, insulation, with either solid or perforated outer panels as required by applications.

D. Fan/motor shall be mounted within the housing on an adjustable slide rail base. Fan/motor assembly must be capable of either horizontal or vertical application.

E. Each fan/motor assembly shall be dynamically balanced to meet AMCA standard 204-96, for fan application class BV-5, to meet or exceed a rotational imbalance Grade .55, producing a maximum rotational imbalance of .022” per second peak, filter in (.55mm per second peak, filter in). “Filter in” measurement indicates that the specified balance grade must be achieved at the submitted design operating speed for the fan(s). Fan and motor assemblies submitted for approval incorporating larger that 215T frame shall be balanced in three orthogonal planes to demonstrate compliance with the G.55 requirement with a maximum rotational imbalance of .022” per second peak filter in (.55 mm per second peak, filter in). Provide factory balance report with units demonstrating compliance to specified balance criteria.

F. Fan and motor assemblies shall be designed for application in multiple fan arrays.

G. Provide motor removal rails.

2.8 FAN BACKDRAFT DAMPERS

A. Each fan applied in multiple fan applications shall be provided with an integral back flow prevention device that automatically (without actuator, mechanical means or weights) prohibits recirculation of air in the event a fan, or fans, become disabled.

B. The system effect for the submitted back flow prevention device shall be included in the calculation to determine the fan TSP for fan selection purposes and shall be indicated as a separate line item SP loss in the submitted fan selection data.

C. Manufacturers other than the basis of design being submitted must provide independent lab certification of fan testing that indicates the system effects attributed to the submitted back flow prevention device in the submitted close coupled mounting arrangement at the inlet of the fan. Fans submitted with discharge dampers or manually installed blank-off plates will not be approved.

D. Back Draft Damper performance data that is based on an AMCA ducted inlet and ducted discharge mounting configuration will not be accepted. Submitted back flow prevention device data must be reflective of close coupled mounting at the intake of the fan(s) per the project design documents. Motorized dampers or other motorized devices submitted for back flow prevention are not acceptable.

E. AHU Manufacturers that do not manufacture the fans being submitted must provide tested and certified performance data for fans as installed in the AHU unit including the back draft damper system effects introduced by close coupled back draft dampers at the fan inlet.

2.9 FAN AIRFLOW MONITORING

A. Each fan shall be supplied with a complete flow measuring system, which indicates airflow in CFM.

B. The flow measuring system shall utilize non-invasive, zero pressure drop flow analog output pressure sensing taps installed in the fan inlet cone for airflow monitoring capability.

C. Provide CFM display and output signal to BAS.

2.10 MOTORS

A. Fan Motor: Comply with requirements in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."

B. All motors shall be standard foot mounted type, TEFC or TEAO motors selected at the specified operating voltage, RPM, and efficiency.

C. Motors shall meet the requirements of NEMA MG-1 Part 30 and 31, section 4.4.2.

D. Motors shall be manufactured by Baldor, Siemens or Toshiba. Motors shall be available in ½ HP increments as nameplate HP ratings from 1.5 HP through 12 HP.

2.11 ACOUSTICAL PERFORMANCE

A. The AHU unit shall provide the specified acoustical performance as scheduled on the drawings for the unit supply discharge opening(s), RA opening(s), and the Outside air and Exhaust air opening(s).

B. Coplanar silencer(s) and/or sound attenuator(s) shall be provided. Sound attenuator cross sectional area shall be selected to not exceed 500 fpm. Losses from sound attenuating devices must be included in the fan performance selection.

C. Manufacturer must provide modeled acoustical performance of the AHU unit.

D. Sound and performance data for approval showing only single fan performance for multiple fan array supplication is not acceptable and will be returned without review.

E. Any proposed remedy for deviations in submitted sound power levels shall be approved by a registered acoustical consultant as selected by the Owner or Architect. Costs for review of the proposed changes shall be borne by the Contractor.

2.12 FAN ARRAY ELECTRICAL

A. Overview:
   1. Provide a complete electrical system required to run the fan array system including all equipment, material, electrical enclosures, electrical components and electrical labor.
   2. Fan array Electrical designs shall be in accordance with the NEC, UL 508A and local codes.

2.13 MOTOR CIRCUIT PROTECTION

A. All motors in the fan array shall be provided with individual Motor Protection for thermal overload protection. All motor circuit protectors shall be located in VFD enclosure.
   1. Multi-drive variable frequency drive control:
      a. Each supply and return fan shall be controlled by an individual ABB Variable Frequency drive. VFD’s shall be installed in a NEMA 4 enclosure, ventilated by conditioned air, which is then EXHAUSTED from AHU.
      b. The Variable Frequency Drives shall be sized accordingly to start and hold each motor in the fan array. Provide short circuit protection through means of fuses with fuse block disconnects or other means of protection.
      c. The Supply Fan Variable Frequency Drives shall be mounted in a dedicated enclosure for connection to the AHU single point 460V power, including main disconnect.

d. A separate Return Fan Variable Frequency Drive enclosure shall be provided with a main disconnecting means. AHU manufacturer to wire from Single point connection to the Return VFD panel so there is a single 460V connection required to AHU. Provide appropriate cooling of both enclosures.
e. Motor circuit protectors shall be used for each motor in the fan array. Motor circuit protectors shall be housed and mounted in the VFD enclosure as required. Variable Frequency Drive enclosure and remote Motor circuit protector enclosure must be mounted at a minimal distance from fan array motors and each other.
f. Provide three phase power distribution wiring and control wiring as required. All three phase power components shall have a rating listed for Short Circuit Current Rating.
g. Provide control wiring and components required for complete operation of the fan array system.

B. Shaft Grounding – Isolated Bearings:
1. Provide either a shaft grounding system or Isolated bearings for each AC motor to prevent electrical damage to motor bearings and extend motor life by safely channeling harmful shaft currents to ground.

2.14 COILS

A. Chilled Water coils shall be of the aluminum plate ripple fin .008”, extended surface or micro channel type rated in accordance with ARI 410 for water.

B. The tubes shall have a minimum .020” wall thickness of seamless copper expanded into the fin collars to provide a permanent mechanical bond. No metallic or thermal bonding materials are acceptable.

C. Return Bends shall be a minimum of one tube thickness greater than the main tubes (0.25) brazed replaceable copper. “U” type shaped tubes is not acceptable.

D. Coil headers shall be non-ferrous seamless Copper (cast iron headers are not acceptable) and provided with Schedule 40 Red Brass male pipe connections. Pipe connections shall be same end connections.

E. Each Coil’s supply & return connections shall be raised / lowered a minimum 6” from the bottom / top of the coil to allow room for piping connection hookup within the vestibule.

F. Each coil shall be provided with capped ½” brass vent & drain connections.

G. Coils shall be fully drainable with no trapped tubes. Coils shall be counter flow design with connections either left or right hand as specified. The use of internal restrictive devices such as turbolater springs or ribbons to obtain turbulent construction is not acceptable.

H. Coil casings shall be minimum 16 gauge 304 Stainless Steel, with formed 3/4” flanges on all sides of the coil with the tube sheets having pressed or extruded tube holes. The coil casing shall be reinforced so that the maximum unsupported length is 60”. The reinforcements shall be of the same material as the casing.

I. Both ends of the coil to be sealed off from the main air stream by full height blank offs on both the entering air and leaving air sides. Blank offs to be the same material as the coil casing.

J. Headers and return bends to be further insulated with a closed cell neoprene gasket the full height & width of the coil casing to reduce condensation.

K. All coils are tested and rated in accordance with the Air Conditioning and Refrigeration Institute (ARI) Standard 410 and certified in accordance with the ARI certification program. All tubes shall be tested at a minimum 450 PSIG and all assemblies tested under water at 450 PSIG for a minimum of 5 minutes and rated for 450 PSIG working pressures. Individual tube and core tests before installation of header are not considered satisfactory. Hydrostatic tests alone will not be acceptable.

L. Coil Supply & Return piping connections extending through the cabinet wall shall be sealed by steel escutcheon plates. The escutcheon plate shall have a rolled collar around the pipe opening to protect the pipe and be equipped with an “O” ring rubber gasket between the collar and the pipe to prevent chaffing and provide an air tight seal around the opening.

2.15 AIR FILTRATION

A. Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

B. Filters shall be arranged for Face side loading. Face loading to be in gasketed Universal Holding Frames. The filter rack assemblies to blanked off to the sides, roof and floor and properly sealed to minimize filter bypass.

C. The Prefilter Section shall be factory fabricated as an integral part of the air handling unit. Filters to be arranged for face loading into a gasketed Universal holding frame. Filters to be 30 % Efficient, MERV-8 UL Class 2. (2) sets of the filters to be provided.

D. Second Filters, arranged for face loading into a gasketed positive sealing Universal Holding Frame to be 90 % Efficient, MERV-13 UL Class 2. (2) sets of filters to be provided.

E. Each filter bank to be provided with a Dwyer Series 2000 Magnehelic Air Filter Gauge with adjustable signal flag. Gauges to be flush mounted. Exterior unit gauges to be covered with a weatherproof enclosure to protect the gauge and prevent hazing of the glass.

F. Provide walk-in filter access sections upstream of each filter rack with adequate space for filter service.

G. Filter banks to be sized so maximum filter face velocity does not exceed 500 fpm.

2.16 LIGHTS/CONTROL WIRING

A. Provide vapor proof or marine type LED light fixtures in each accessible section (quantity in each section to be as shown on drawings) complete with a protective metal cage and sealed glass enclosure.

B. Lights to be wired to a common switch mounted in a weatherproof box adjacent to the fan access door complete with a duplex convenience outlet, 115-V, ground-fault-interrupter type with 20-A overcurrent protection.

C. Power shall be 120v/1/60.

D. All wiring to lights, switches and outlet(s) shall be in conduit and internal to the unit. No external conduit runs for the lights are allowed.

E. Junction boxes shall be furnished at unit splits to allow the electrical contractor to make final connections in the field. Wiring to be clearly labeled at junction points to facilitate reconnection.

F. Lights and convenience outlets shall be on an electrical circuit separate from the fan arrays, controls, and other operation related items.

2.17 AIR FLOW MEASURING STATIONS

A. Refer to drawings for additional details and requirements. Airflow monitoring stations are to be provided and installed at the factory by the air handling unit manufacturer. Interface with Building Automation System. Refer to drawings for additional information.

B. Each device shall be designed and built to comply with, and provide results in accordance with, accepted practice as defined for system testing in the ASHRAE Handbook of fundamentals, as well as in the Industrial Ventilation Handbook.

C. Approved manufacturer: Ruskin model EAMP with Ruskin CD60 motorized damper or prior approved equal.

D. Furnish and install, at locations shown on plans or as in accordance with schedules, an electronic thermal dispersion type airflow temperature measuring station (AFTMS).
   1. AFTMS shall be capable of monitoring and reporting the airflow and temperature at each measuring location.
   2. AFTMS shall consist of multiple measuring probes and sensor points and a control transmitter that communicates with the building automation system (BAS).

E. Probes shall be constructed of an airfoil shaped 6063T5 aluminum extrusion ensuring the lowest pressure drop and noise generation.

F. Individual probes shall include one or more sensor circuits encased in an UL 94 flame rated, high impact, ABS shroud.

G. Each sensor circuit shall consist of an epoxy coated ambient thermistor, an epoxy coated heated thermistor and a microprocessor mounted to a printed circuit board (PCB).

H. All sensor circuits shall be wired through a continuous, UL plenum rated, ribbon cable and secured through a PCB connector to ensure a rigid connection to the sensor circuit.

I. Soldering thermistor leads to loose wires is not an acceptable practice.

J. Each sensor circuit shall terminate in a microprocessor-based multiplexer at the end of each probe.

K. Probe multiplexer shall digitally communicate the average airflow and temperature to the microprocessor-based control transmitter.

L. Analog signals between the probe and transmitter are unacceptable.

M. Readily available UL Plenum rated CAT5 communications cable with square terminal connectors, dust boot covers and gold plated contacts shall be utilized.

N. Communications cable shall be a minimum of ten feet in length and shall be available up to 50 feet if required.

O. Control transmitter shall be capable of processing up to 16 independent sensing points per airflow measuring location and shall operate on a fused 24 VAC supply.

P. Control transmitter shall feature a 16x2 character alphanumeric LCD display, digital offset/gain adjustment, continuous performing sensor/transmitter diagnostics and a visual alarm to detect malfunctions.

Q. LCD shall be field adjustable to display either I.P or S.I. units. Transmitter output shall be field adjustable 4-20 mA or 2-10 VDC. AFTMS shall be in all respects equivalent to Ruskin model EAMP

2.18 DAMPERS

A. Control Dampers:

1. Provide in accordance with schedules, Low Leak Dampers with published leakage data certified under the AMCA certified ratings program.

2. Low Leak Dampers shall be rated less than 10 cfm per sq. ft. of area at 4-in. w.g. pressure difference through a 48” x 48” damper.

3. Low leak dampers shall be fabricated of steel or aluminum with hat mounting flanges on both sides of the frame.

4. Blades shall be mechanically locked in extruded blade slots, yet be easily replaceable in the field. Adhesive or clip-on type blade seals are not acceptable. Bearings shall be non-corrosive molded synthetic.

5. Axles shall be square or hexagonal (round is not acceptable) to provide positive locking connection to blades and linkage. Linkage shall be concealed in the frame.

2.19 CONTROLS

A. Control equipment and sequence of operation are specified in Section 23 09 23 “Instrumentation and Controls Systems for HVAC.”

2.20 ACCESSORIES

A. Filter differential pressure sensor compatible with BAS as specified in Section 23 09 23 “Instrumentation and Controls Systems for HVAC.”

2.21 TEST PORTS

A. Provide 1” diameter test ports for unit air stream testing in each plenum section between each component within the AHU. Test ports shall have a tube that extends between the inside and outside of the unit and a screwed cap on the exterior to allow access. The test ports shall have been flanged on the exterior to allow air seal and shall be flanged on the interior to cover the penetration of the casing.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Unit Support: Install unit level on structural concrete housekeeping pad. Coordinate wall penetrations and flashing with wall construction. Secure AHUs to structural support with anchor bolts.

B. Install condensate drain, minimum connection size, with trap and indirect connection to nearest floor sink.

C. Duct installation requirements are specified in other Division 23 Sections. Drawings indicate the general arrangement of ducts. The following are specific connection requirements:
1. Install ducts to termination at duct connections on unit.
2. Connect ducts to AHUs with flexible duct connectors specified in Section 23 33 00 "Air Duct Accessories."

3.2 STARTUP SERVICE

A. Provide factory start-up services and owner training for air handling units and VFD’s. Supplier to provide as many days as needed for complete start-up, including coordination with electrical/controls/test and balance contractors and participation in the commissioning process.

B. A factory authorized representative shall perform on-site inspections and instruction and be responsible for ensuring that the field assembly is acceptable to the manufacturer.

C. Unit shall be swept and vacuumed clean.

D. Complete installation and startup checks according to manufacturer’s written instructions.

E. Install new, clean filters.

3.3 FIELD QUALITY CONTROL

A. Complete the manufacturer's installation and startup checklists and resolve all discrepancies.

B. Provide the Commission Agent and Owner PM with the completed checklists/test results.

3.4 TRAINING

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

END OF SECTION

SECTION 23 73 43

PACKAGED, OUTDOOR, ROOFTOP UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes packaged, outdoor, central-station air-handling units (rooftop units) with the following components and accessories:
   1. Direct-expansion cooling.
   2. Electric-heating coils.
   3. Economizer outdoor- and return-air damper section.
   4. Integral, space temperature controls.
   5. Roof curbs.

1.2 DEFINITIONS

A. Outdoor-Air Refrigerant Coil: Refrigerant coil in the outdoor-air stream to reject heat during cooling operations and to absorb heat during heating operations. "Outdoor air" is defined as the air outside the building or taken from outdoors and not previously circulated through the system.

B. Outdoor-Air Refrigerant-Coil Fan: The outdoor-air refrigerant-coil fan in RTUs. "Outdoor air" is defined as the air outside the building or taken from outdoors and not previously circulated through the system.

C. RTU: Rooftop unit. As used in this Section, this abbreviation means packaged, outdoor, central-station air-handling units. This abbreviation is used regardless of whether the unit is mounted on the roof or on a concrete base on ground.

D. Supply-Air Fan: The fan providing supply-air to conditioned space. "Supply air" is defined as the air entering a space from air-conditioning, heating, or ventilating apparatus.

E. Supply-Air Refrigerant Coil: Refrigerant coil in the supply-air stream to absorb heat (provide cooling) during cooling operations and to reject heat (provide heating) during heating operations. "Supply air" is defined as the air entering a space from air-conditioning, heating, or ventilating apparatus.

F. VVT: Variable-air volume and temperature.

1.3 ACTION SUBMITTALS

A. Product Data: Manufacturer's technical data for each RTU.

1. Include rated capacities, dimensions, required clearances, characteristics, furnished specialties, and accessories.
2. Include equipment dimensions, weights, and structural loads, required clearances, method of field assembly, components, and location and size of each field connection.

B. 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.

1. Wiring Diagrams: Power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

A. Field quality-control test reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.6 QUALITY ASSURANCE

A. ASHRAE Compliance:

1. Comply with ASHRAE 15 for refrigerant system safety.
2. Comply with ASHRAE 33 for methods of testing cooling and heating coils.
3. Comply with applicable requirements in ASHRAE 62.1, Section 5 "Systems and Equipment" and Section 7 "Construction and Startup."
4. Applicable requirements in ASHRAE/IESNA 90.1, Section 6 “Heating, Ventilating, and Air-Conditioning."

B. NFPA Compliance: Comply with NFPA 90A and NFPA 90B.

C. UL Compliance: Comply with UL 1995.

D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.7 COORDINATION

A. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section 03 30 00 "Cast-In-Place Concrete" and Section 03 30 53 "Miscellaneous Cast-In-Place Concrete."

B. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Section 07 72 00 "Roof Accessories."

C. Coordinate location of piping and electrical rough-ins.

1.8 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to replace components of RTUs that fail in materials or workmanship within specified warranty period.

1. Warranty Period for Compressors & Gas Furnace Heat Exchangers: Manufacturer's standard, but not less than five years from date of Substantial Completion.
2. Warranty Period for Solid-State Ignition Modules: Manufacturer's standard, but not less than three years from date of Substantial Completion.
3. Warranty Period for Control Boards: Manufacturer's standard, but not less than three years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

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

1. Daikin
2. Trane; American Standard Companies, Inc.
3. YORK International Corporation/JCI.

2.2 CASING

A. General Fabrication Requirements for Casings: Formed and reinforced double-wall insulated panels, fabricated to allow removal for access to internal parts and components, with joints between sections sealed.

B. Exterior Casing Material: Galvanized steel with factory-painted finish, with pitched roof panels and knockouts with grommet seals for electrical and piping connections and lifting lugs.

1. Exterior Casing Thickness: minimum 0.052 inch (18ga) thick.

C. Inner Casing Fabrication Requirements:

1. Inside Casing: Galvanized steel, minimum 0.034 inch (21ga).

D. Casing Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.

1. Materials: ASTM C 1071, Type I.
2. Thickness: 1 inch.
3. Liner materials shall have air-stream surface coated with an erosion- and temperature-resistant coating or faced with a plain or coated fibrous mat or fabric.

E. Condensate Drain Pans: Formed sections of stainless-steel sheet or composite plastic, a minimum of 2 inches deep, and complying with ASHRAE 62.1.

1. Double-Wall Construction: Fill space between walls with foam insulation and seal moisture tight.
2. Drain Connections: Threaded nipple.
3. Pan-Top Surface Coating: Corrosion-resistant compound.

2.3 FANS

A. Direct-Driven Supply-Air Fans: Double width, forward curved or backward inclined, centrifugal; with permanently lubricated, multispeed motor resiliently mounted in the fan inlet. Aluminum or painted-steel wheels, and galvanized- or painted-steel fan scrolls.

B. Belt-Driven Supply-Air Fans: Double width, forward curved, centrifugal; with permanently lubricated, single-speed motor installed on an adjustable fan base resiliently mounted in the casing. Aluminum or painted-steel wheels, and galvanized- or painted-steel fan scrolls.

C. Condenser-Coil Fan: Propeller, mounted on shaft of permanently lubricated motor.

D. Relief-Air Fan: Propeller, forward curved or Backward inclined, shaft mounted on permanently lubricated motor.

E. Seismic Fabrication Requirements: Fabricate fan section, internal mounting frame and attachment to fans, fan housings, motors, casings, accessories, and other fan section components with reinforcement strong enough to withstand seismic forces defined in Section 23 05 48 "Vibration and Seismic Controls for HVAC Piping and Equipment" when fan-mounted frame and RTU-mounted frame are anchored to building structure.

F. Fan Motor: Comply with requirements in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."

2.4 COILS

A. Supply-Air Refrigerant Coil:
   1. Aluminum-plate fin and seamless copper tube with microchannel configuration in steel casing with equalizing-type vertical distributor.
   2. Polymer strip shall prevent all copper coil from contacting steel coil frame or condensate pan.
   3. Coil Split: Interlaced.
   4. Condensate Drain Pan: Stainless steel formed with pitch and drain connections.

B. Outdoor-Air Refrigerant Coil:
   1. Aluminum-plate fin and seamless copper tube with microchannel configuration in steel casing with equalizing-type vertical distributor.
   2. Polymer strip shall prevent all copper coil from contacting steel coil frame or condensate pan.

C. Electric-Resistance Heating:
   1. Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium, supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized- steel frame. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.
   2. Overtemperature Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box.
   3. Overcurrent Protection: Manual-reset thermal cutouts, factory wired in each heater stage.
   4. Control Panel: Unit mounted with disconnecting means and overcurrent protection. Include the following controls:
      a. SCR Controller: Pilot lights operate on load ratio, a minimum of five steps.
      b. Time-delay relay.
      c. Airflow proving switch.

2.5 REFRIGERANT CIRCUIT COMPONENTS

A. Compressor: Hermetic: scroll, or screw, mounted on vibration isolators; with internal overcurrent and high-temperature protection, internal pressure relief.

B. Refrigeration Specialties:
   1. Refrigerant: R-407C or R-410A.
   2. Expansion valve with replaceable thermostatic element.
   3. Refrigerant filter/dryer.
   4. Manual-reset high-pressure safety switch.
   5. Automatic-reset low-pressure safety switch.
   6. Minimum off-time relay.
   7. Automatic-reset compressor motor thermal overload.
   8. Brass service valves installed in compressor suction and liquid lines.

2.6 AIR FILTRATION

A. Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
   1. Glass Fiber: Minimum 2 inch thick pleated media MERV-13

2.7 DAMPERS

A. Economizer: Outdoor- and Return-Air Mixing Dampers: Parallel- or opposed-blade galvanized-steel dampers mechanically fastened to cadmium plated for galvanized-steel operating rod in reinforced cabinet. Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously.
   1. Damper Motor: Modulating with adjustable minimum position.

2. Relief-Air Fan and Damper: Motorized, as required by ASHRAE/IESNA 90.1, with bird screen and hood.

2.8 ELECTRICAL POWER CONNECTION

A. Provide for single connection of power to unit with unit-mounted disconnect switch accessible from outside unit and control-circuit transformer with built-in overcurrent protection.

B. Provide a separate electrical circuit for convenience lighting and 20A receptacle.

2.9 CONTROLS

A. Control equipment and sequence of operation are specified in Section 23 09 23 "Instrumentation and Controls for HVAC."

B. Basic Unit Controls:
   1. Control-voltage transformer.
   2. BACnet unitary controller or
   3. Wall-Mounted Thermostat

C. Electronic Controller:
   1. Controller shall have volatile-memory backup.
   2. Safety Control Operation:
      a. Smoke Detectors: Stop fan and close outdoor-air damper if smoke is detected. Provide additional contacts for alarm interface to fire alarm control panel.
      b. Firestats: Stop fan and close outdoor-air damper if air greater than 130 deg F enters unit. Provide additional contacts for alarm interface to fire alarm control panel.
      c. Fire Alarm Control Panel Interface: Provide control interface to coordinate with operating sequence described in Division 28.
   3. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of two programmable periods per day.
   4. Unoccupied Period:
   5. Supply Fan Operation:
      a. Occupied Periods: Run fan continuously.
      b. Unoccupied Periods: Cycle fan to maintain setback temperature.
   6. Refrigerant Circuit Operation:
      a. Occupied Periods: Cycle or stage compressors to match compressor output to cooling load to maintain room temperature. Cycle condenser fans to maintain maximum hot-gas pressure.
      b. Unoccupied Periods: Compressors off.
   7. Electric-Heating-Coil Operation:
   8. Fixed Minimum Outdoor-Air Damper Operation:
   9. Economizer Outdoor-Air Damper Operation:

D. Interface Requirements for HVAC Instrumentation and Control System shall be in accordance with Section 23 09 23 "Instrumentation and Controls for HVAC."

2.10 ACCESSORIES

A. Thermostatic expansion valve or EXV.

B. Time-Delay Relay: Continues operation of evaporator fan after compressor shuts off.

C. Reversing valve.

D. Low-Ambient Controller: To permit operation down to 0 deg. F.

E. Electric heater with integral thermostat maintains minimum 50 deg F temperature in gas burner compartment.

F. Duplex, 115-V, ground-fault-interrupter outlet with 20-A overcurrent protection. Include transformer if required

G. Filter differential pressure sensor in accordance with Section 23 09 23 "Instrumentation and Controls for HVAC."

H. Coil guards.

I. Hail guards.

2.11 ROOF CURBS

A. Roof curbs with vibration isolators and wind or seismic restraints are specified in Section 23 05 48 "Vibration and Seismic Controls for HVAC Piping and Equipment."

B. Materials: Galvanized steel with corrosion-protection coating, watertight gaskets, and factory-installed wood nailer; complying with NRCA standards.
   1. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
      a. Materials: ASTM C 1071, Type I or II.
      b. Thickness: 1-1/2 inches.

C. Wind and Seismic Restraints: Metal brackets compatible with the curb and casing, painted to match RTU, used to anchor unit to the curb, and designed for loads at Project site. Comply with requirements in Section 23 05 48 "Vibration and Seismic Controls for HVAC Piping and Equipment" for wind-load requirements.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install units level and plumb, firmly anchored in locations indicated.

B. Maintain manufacturer's recommended clearances for service and maintenance.

C. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

D. Roof Curb: Install on roof structure or concrete base, level and secure. Install RTUs on curbs and coordinate roof penetrations and flashing with roof construction specified in Section 07 72 00 "Roof Accessories." Secure RTUs to upper curb rail, and secure curb base to roof framing or concrete base with anchor bolts.

E. Unit Support: Install unit level on structural curbs. Coordinate wall penetrations and flashing with wall construction. Secure RTUs to structural support with anchor bolts.

F. Install wind and seismic restraints according to manufacturer's written instructions.

G. Install condensate drain, minimum connection size, with trap and indirect connection to nearest drain.

H. Duct installation requirements are specified in other HVAC Sections. Drawings indicate the general arrangement of ducts. The following are specific connection requirements:
   1. Install ducts to termination at top of roof curb.
   2. Remove roof decking only as required for passage of ducts. Do not cut out decking under entire roof curb.
   3. Connect supply ducts to RTUs with flexible duct connectors specified in Section 23 33 00 "Air Duct Accessories."
   4. Install return-air duct continuously through roof structure.
   5. If required by construction documents, provide a normal-weight, 3000-psi, compressive strength (28-day) concrete mix inside roof curb, 4 inches thick. Concrete, formwork, and reinforcement are specified with concrete.

3.2 FIELD QUALITY CONTROL

A. Complete the manufacturer’s installation and startup checklists and resolve all discrepancies.

B. Provide the Commission Agent and Owner PM with the completed checklists/test results.

C. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections, and to assist in testing.

D. Tests and Inspections:
   1. Perform each visual and mechanical inspection and electrical test. Certify compliance with test parameters.
   2. Leak Test: After installation, charge system with refrigerant and oil and test for leaks. Repair leaks, replace lost refrigerant and oil, and retest until no leaks exist.

3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor operation and unit operation, product capability, and compliance with requirements.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
5. Verify proper airflow over coils.

E. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.

F. Compressor and condenser units will be considered defective if they do not pass tests and inspections.

G. Prepare test and inspection reports.

3.3 TRAINING

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

END OF SECTION

SECTION 23 74 33

DEDICATED OUTDOOR AIR UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes factory-packaged units capable of supplying up to 100 percent outdoor air and providing cooling:

1. Packaged outdoor air unit.
2. Heat exchanger.
3. Refrigeration components.
4. Unit operating controls.
5. Roof curb.
6. Electrical power connections.
7. Operation and maintenance service.

1.2 REFERENCES

A. NFPA 90 A & B - Installation of Air Conditioning and Ventilation Systems and Installation of Warm Air Heating and Air Conditioning Systems. (All)

B. UL or ETL Listed and Labeled.

C. ANSI/ASHRAE 15 - Safety Code for Mechanical Refrigeration. (all)

D. Standard for Safety Heating and Cooling Equipment – Third Edition, UL 1995/CSA C22.2 236-05, dated February 18, 2005, with revisions through July 30, 2009 (all for cooling and for electric heat).

E. Standard for Gas Unit Heaters and Gas-Fired Duct Furnaces ANSI Z83.8-2006, CSA 2.6-2006, Third Edition – 2006 (indirect gas-fired/e).

F. Standard for Non-Recirculating Direct Gas-Fired Industrial Air Heaters, ANSI Z83.4/CSA 3.7 - 2003 with addenda ANSI Z83.4/CSA 3.7 - 2004a and addenda ANSI Z83.4/CSA 3.7 - 2006b (direct gas-fired/e).

G. ANSI/ASHRAE/IESNA 90.1-2010 - Energy Standard for New Buildings except Low-Rise Residential Buildings.

H. ANSI Z21.47/UL1995 - Unitary Air Conditioning Standard for safety requirements.

I. ANSI/NFPA 70-1995 - National Electric Code.

J. International Fuel Gas Code.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product. Include rated capacities, operating characteristics, and furnished specialties and accessories.
   1. Submit specifications for unit and accessories describing construction, components and options.
   2. Submit data on electrical requirements and connection points. Include recommended wire and fuse sizes or MCA, sequence of operation, safety and start-up instructions.

B. Shop drawings submitted for approval shall be accompanied by a copy of the purchase agreement between the Contractor and an authorized service representative of the manufacturer for check, test and start up, and warranty service.

C. Shop Drawings:
   1. Include plans, elevations, sections, and attachment details.
   2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   3. Prepare the following by or under the supervision of a qualified professional engineer:
      a. Mounting Details: For securing and flashing roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
      b. Include diagrams for power, signal, and control wiring.
   4. Unit fabrication and assembly details.
   5. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.

D. Shop Drawings shall be accompanied by a copy of the purchase agreement between the Contractor and an authorized service representative of the manufacturer for check, test and start up, and warranty service.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Roof-curb mounting details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
   1. Size and location of unit-mounted rails and anchor points and methods for anchoring units to roof curb.
   2. Required roof penetrations for ducts, pipes, and electrical raceways, including size and location of each penetration.

B. Manufacturer’s startup service reports.

C. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For units to include in emergency, operation, and maintenance manuals.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Unit shall be shipped with doors bolted shut and outside air hood closed to prevent damage during transport and thereafter while in storage awaiting installation. Horizontal configuration units shall include panels coving air intake and discharge openings.

B. Follow Installation, Operation and Maintenance manual instructions for rigging, moving, and unloading the unit at its final location.

C. Unit shall be stored in a clean, dry place protected from construction traffic in accordance with the Installation, Operation and Maintenance manual.

D. Protect units from physical damage. Leave factory shipping covers in place until installation.

1.7 REGULATORY REQUIREMENTS

A. Unit shall conform to the appropriate standards listed in Section 103.
   1. In the event the unit is not approved by a Nationally Recognized Testing Laboratory (NRTL) for compliance with the appropriate standards, the manufacturer shall, at manufacturer’s expense, provide for a field certification and labeling of unit by an NRTL to the appropriate standards. Manufacturer shall, at manufacturer’s cost, complete and modifications required by NRTL prior to certification and field labeling. Manufacturer shall include coverage of all modifications in unit warranty.

1.8 EXTRA MATERIALS

A. Provide two extra sets of filters.

B. Provide one extra set of belts for belt drive units.

1.9 WARRANTY

A. Special Warranty: Manufacturer agrees to replace components of units that fail in materials or workmanship within specified warranty period.
   1. Warranty Period for Compressors: Five years from date of Substantial Completion.
   2. Warranty Period for Heat Exchangers: 20 years from date of Substantial Completion.
   3. Warranty Period for remainder of unit: Two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 SUMMARY

A. The contractor shall furnish and install packaged dedicated outdoor air unit(s) as shown and scheduled on the Contract Documents. Unit(s) shall perform at the specified conditions as scheduled.

B. Approved Manufacturers:
1. Daikin – Basis of Design.
2. Trane: Model OAU (Packaged Outdoor Air Unit) – Approved Equal.
3. Aaon – Only if application requires this and no one else can match.
4. Substitutions: Contractor shall be responsible for electrical and mechanical and structural modifications required when substituting a product other than the specified product. It shall be the responsibility of the bidding contractor to make the specifier aware of said modifications. As built drawing changes are the responsibility of the contractor submitting the substitution.

2.2 ROOFTOP UNITS

A. General: Packaged rooftop unit shall include compressors, evaporator coils, filters, supply fans, dampers, air-cooled condenser coils, condenser fans, water-cooled condensers, reheat coil, gas heaters, electric heaters, hot water coil, steam coil, exhaust fans, return fans, energy recovery wheels, and unit controls as indicated on schedules on drawings.
1. Outdoor air handling unit shall include filters, supply fans, dampers, chilled water coils, DX evaporator coils, gas heaters, electric heaters, hot water coil, steam coil, exhaust fans, return fans, energy recovery wheels, and unit controls as indicated on schedules on drawings.
2. Unit shall be factory assembled and tested including leak testing of the coils, pressure testing of the refrigeration circuit, and run testing of the completed unit. Run test report shall be supplied with the unit in the controls compartment’s literature pocket.
3. Unit shall have decals and tags to indicate lifting and rigging, service areas and caution areas for safety and to assist service personnel.
4. Unit components shall be labeled, including pipe stub outs, refrigeration system components and electrical and controls components.
5. Estimated sound power levels (dB) shall be shown on the unit ratings sheet.
6. Installation, Operation and Maintenance manual shall be supplied within the unit.
7. Laminated color-coded wiring diagram shall match factory installed wiring and shall be affixed to the interior of the control compartment’s access door.
8. Unit nameplate shall be provided in two locations on the unit, affixed to the exterior of the unit and affixed to the interior of the control compartment’s access door.

B. Construction:

1. Cabinet walls, access doors, and roof shall be fabricated of double wall, impact resistant, rigid polyurethane foam panels.
2. Unit insulation shall have a minimum thermal resistance R-value of 13. Foam insulation shall have a minimum density of 2 pounds/cubic foot and shall be tested in accordance with ASTM D-1929-11 for a minimum flash ignition temperature of 610°F.
3. Unit construction shall be double wall with G90 galvanized steel on both sides and a thermal break.
4. Cabinet leakage shall not exceed 1% of total airflow when tested at 3 times the minimum external static pressure provided in AHRI Standard 340/360. Panel deflection shall not exceed L/240 ratio at 8 inches water column of positive or negative static pressure. Deflection shall be measured at the midpoint of the panel height and width. Continuous sealing shall be included between panels and between access doors and openings to reduce air leakage. Refrigerant piping and electrical conduit through cabinet panels shall include sealing to reduce air leakage.
5. Roof of the air tunnel shall be sloped to provide complete drainage. Cabinet shall have rain break overhangs above access doors.
6. Access to filters, dampers, cooling coils, reheat coil, heaters, energy recovery wheels, compressors, water-cooled condensers, and electrical and controls components shall be through hinged access doors with quarter turn, lockable handles. Full length stainless steel piano hinges shall be included on the doors.
7. Exterior paint finish shall be capable of withstanding at least 2,500 hours, with no visible corrosive effects, when tested in a salt spray and fog atmosphere in accordance with ASTM B 117-95 test procedure.
8. Units with cooling coils shall include double sloped composite plastic or 304 stainless steel drain pans.
9. Unit shall include lifting lugs.

C. ACCESS DOORS

1. Access doors shall be double wall construction. Door jam & frame shall be constructed with continuously welded corners for rigidity. Door panels shall be insulated with expandable urethane foam insulation completely encapsulated and sealed between the door panels and frame. Provide doors located and sized to allow for routine maintenance including motor replacement and filter replacement, electrical components and any other sections or components requiring access or maintenance. Provide test ports in all doors into air tunnel.
2. Doors shall be provided with a minimum (2) dual acting heavy duty composite latches through 48” high, (3) latches through 72” high. Latches shall be operable from both the interior and exterior of the unit. Door hinge shall be Stainless Steel heavy duty self-aligning. Door shall be sealed with continuous hollow closed cell foam gasket.

3. Doors shall open against static pressure. Doors used to access rotating equipment shall be provided with an OSHA approved safety latching mechanism. Doors with access to moving parts must meet current UL mechanical protection guidelines. Standard door size shall be 24” wide by 60” high unless restricted by height or section width.
4. Doors shall be provided with double pane wire reinforced glass viewing windows as called out for on the unit drawings in the specifications. Minimum window size to be 9” x 9”.

D. Accessories:
1. Unit base pan shall be provided with 1/2 inch thick foam insulation.
2. Unit shall include factory wired control panel compartment LED service lights. Lights to be wired to a common switch mounted in a weatherproof box adjacent to the access door complete with a duplex convenience outlet, 115-V, ground-fault-interrupter type with 20A overcurrent protection. Power shall be 120v/1/60. Lights and convenience outlets shall be on an electrical circuit separate from the fans, compressors, controls, and other operation related items.
3. Unit shall include factory installed, painted galvanized steel condenser coil guards on the face of the condenser coil.

E. Supply Fans:
1. Unit shall include direct drive, unhoused, backward curved, plenum supply fans.
2. Blowers and motors shall be dynamically balanced and mounted on rubber isolators.
3. Motors shall be premium efficiency ODP with ball bearings rated for 200,000 hours service with external lubrication points.
4. Variable frequency drives shall be factory wired and mounted in the unit. Fan motors shall be premium efficiency. Motor shall include shaft grounding.

F. Exhaust Fans:
1. Exhaust dampers shall be sized for 100% relief.
2. Fans and motors shall be dynamically balanced.
3. Motors shall be premium efficiency ODP with ball bearings rated for 200,000 hours service with external lubrication points.
4. Access to exhaust fans shall be through double wall, hinged access doors with quarter turn handles.
5. Variable frequency drives shall be factory wired and mounted in the unit. Fan motors shall be premium efficiency. Motor shall include shaft grounding.
6. Unit shall include belt driven, unhoused, backward curved, plenum exhaust fans.

G. Cooling Coils:
1. Direct Expansion Evaporator Coils:
    a. Coils shall be designed for use with R-410A refrigerant and constructed of copper tubes with aluminum fins mechanically bonded to the tubes and galvanized steel end casings. Fin design shall be sine wave rippled.

b. Coils shall have interlaced circuitry when unit has multiple circuits.
c. Coils shall be helium or hydrogen leak tested.
d. Coils shall be furnished with a factory installed expansion valves.

2. Chilled Water Cooling Coils:
a. Coils shall be certified in accordance with AHRI Standard 410 and be helium or hydrogen leak tested.
b. Coil shall be constructed of copper tubes with aluminum fins mechanically bonded to the tubes and galvanized steel end casings. Fin design shall be sine wave rippled.
c. Control valves shall be field supplied and field installed by the controls contractor.

H. Refrigeration System:
1. Unit shall be factory charged with R-410A refrigerant.
2. Compressors shall be scroll type with thermal overload protection and carry a 5 year non-prorated warranty, from the date of original equipment shipment from the factory. Compressors shall be variable capacity scroll compressor on the lead refrigeration circuit which shall be capable of modulation from 10-100% of its capacity, and unit shall include two-stage compressors on that lag refrigeration circuit(s).
3. Unit shall include factory provided and installed compressor sound jackets on all compressors.
4. Compressors shall be mounted in an isolated service compartment which can be accessed without affecting unit operation. Lockable hinged compressor access doors shall be fabricated of double wall, rigid polyurethane foam insulated panels to prevent the transmission of noise outside the cabinet.
5. Compressors shall be isolated from the base pan with the compressor manufacturer’s recommended rubber vibration isolators, to reduce transmission of noise from the compressors into the building area.
6. Each refrigeration circuit shall be equipped with expansion valve type refrigerant flow control.
7. Each refrigeration circuit shall be equipped with automatic reset low pressure and manual reset high pressure refrigerant safety controls, Schrader type service fittings on both the high pressure and low pressure sides, and factory installed liquid line filter driers.
8. Each refrigeration circuit shall be equipped with a liquid line sight glass and suction and discharge compressor isolation valves.
9. Each capacity stage shall be equipped with a 5 minute off, delay timer to prevent compressor short cycling.
10. Refrigeration circuit(s) shall be provided with aluminum microchannel hot gas reheat coil, modulating valves, electronic controller, supply air temperature sensor and a dehumidification control signal terminal which allow the unit to have a dehumidification mode of operation, which includes supply air temperature control to prevent supply air temperature swings and overcooling of the space.

I. Options as indicated on schedules on Drawings.

1. Unit shall be configured as an air-source heat pump. Each refrigeration circuit shall each be equipped with a factory installed liquid line filter drier with check valve, reversing valve, accumulator, and expansion valves on both the indoor and outdoor coils. Reversing valve shall energize during the heat pump cooling mode of operation.
2. Unit shall be configured as a water-source heat pump. Each refrigeration circuit shall each be equipped with a factory installed liquid line filter drier with check valve, reversing valve, and expansion valves on both the indoor coil and refrigerant-to-water heat exchanger. Reversing valve shall energize during the heat pump cooling mode of operation.
3. Lead refrigeration circuit shall be equipped with flooded condenser low ambient head pressure control to allow operation down to 0°F. Option includes an adjustable compressor lockout.

J. Condensers:

1. Air-Cooled Condenser:
   a. Condenser fans shall be vertical discharge, axial flow, direct drive fans.
   b. Coils shall be designed for use with R-410A refrigerant.
   c. Coils shall be multi-pass and fabricated from aluminum microchannel tubes.
   d. Heat pump outdoor coil shall be constructed of copper tubes with aluminum fins mechanically bonded to the tubes and aluminum end casings. Fin design shall be sine wave rippled.
   e. Coils shall be designed for a minimum of 10 degrees F of refrigerant sub-cooling.
2. Options as indicated on schedules on Drawings:
   a. Condenser fans shall be high efficiency electronically commutated motor driven with factory installed head pressure control module. Condenser airflow shall continuously modulate based on head pressure and cooling operation shall be allowed down to 35°F with adjustable compressor lockout.
   b. Condenser fans shall be low sound, high efficiency electronically commutated motor driven with factory installed head pressure control module. Condenser airflow shall continuously modulate based on head pressure and cooling operation shall be allowed down to 35°F. Condenser fan housing shall be fabricated of composite material and include an optimized orifice with inlet guide vanes. The condenser fan blade shall be serrated and aerodynamically designed for high efficiency and reduced sound levels.
3. Water Cooled Condenser:
   a. Water-cooled condensing section shall contain plate type, heat exchangers located in an insulated vestibule. Heat exchangers shall be circuited in a counter flow arrangement to the refrigerant system. Plates shall be stainless steel. Each heat exchanger shall be provided with a removable and cleanable type, basket filter on the waterside circuit. Field piping connections shall be made at each plate heat exchanger within the condensing section of the rooftop unit. Maximum operating pressure on the water side of the condenser shall be 125 psi.

b. Field installed piping shall be hydrostatically tested before being put into service. Test pressure shall be 125 psi for a two hour duration. Leaks and loss in test pressure constitute defects. If test fails, corrections shall be made to the system and the test shall then be repeated to make certain defects were corrected. Testing shall be performed to ASTM Standards.

c. Each heat exchanger circuit shall have a factory installed ball valve for water balancing, a flow switch that shuts down the compressors if water flow to the condenser is interrupted and a factory installed motorized shutoff valve.

K. Gas Heating:

1. Unit shall include a High Turndown Modulating Natural Gas Furnace equipped with modulating gas valves, adjustable speed combustion blowers, stainless steel tubular heat exchangers, and electronic controller. Combustion blowers and gas valves shall be capable of modulation.
2. Electronic controller shall include a factory wired, field installed supply air temperature sensor. Sensor shall be field installed in the supply air ductwork.
3. Supply air temperature setpoint shall be adjustable on the electronic controller within the controls compartment.
4. Gas heater shall be capable of minimum capacity turndown ratio of 10:1. Heat exchanger furnace shall carry a 15 year non-prorated warranty, from the date of substantial completion.
5. Furnace shall include a gas ignition system consisting of an electronic igniter to a pilot system, which will be continuous when the heater is operating, but will shut off the pilot when heating is not required.

L. Electric Heating:

1. Unit shall include an include electric heater consisting of electric heating coils, fuses, and a high temperature limit switch, with capacities as shown on the plans.
2. Electric heating coils shall be located in the reheat position downstream of the supply fans.
3. Electric heater shall have full modulation capacity controlled by an SCR (Silicon Controlled Rectifier). Supply air temperature sensor shall be factory provided and field installed in the supply air ductwork. A setpoint adjustment potentiometer shall be factory provided.
4. Auxiliary electric heating capacity shall be sized to meet heating leaving air temperature setpoint when heat pump heating is in operation.

M. Filters:

1. Unit shall include 2 inch thick, pleated panel filters with an ASHRAE MERV rating of 8, upstream of the cooling coil.
2. Unit shall include a Magnehelic gauge mounted in the controls compartment.

N. Outside Air/Economizer:

1. Unit shall include 0-100% economizer consisting of a motor operated outside air damper and return air damper assembly constructed of extruded aluminum, hollow core, airfoil blades with rubber edge and end seals.

2. Damper blades shall be gear driven and designed to have no more than 20 cfm of leakage per sq ft. at 4 in. w.g. air pressure differential across the damper. Low leakage dampers shall be Class 2 AMCA certified, in accordance with AMCA Standard 511. Damper assembly shall be controlled by spring return actuator. Unit shall include outside air opening bird screen, outside air hood and barometric relief dampers. Economizer shall be furnished with a Fault Detection and Diagnostic package with BACnet interface.
3. Unit shall include outside airflow measuring station and airflow signal processor that communicates directly with the factory provided control systems or can also be used with customer provided controls with a BACnet interface and 0-10 VDC output signal.

O. Energy Recovery as indicated on schedules on Drawings.
1. Unit shall contain a factory mounted and tested energy recovery wheel. The energy recovery wheel shall be mounted in a rigid frame containing the wheel drive motor, drive belt, wheel seals and bearings.
2. Wheel frame shall slide out for service and removal from the cabinet
3. The energy recovery cassette shall be an Underwriters Laboratories Recognized Component for electrical and fire safety. The wheel drive motor shall be an Underwriters Laboratory Recognized Component and shall be mounted in the cassette frame and supplied with a service connector or junction box. Thermal performance shall be certified by the manufacturer in accordance with ASHRAE Standard 84, Method of Testing Air-to-Air Heat Exchangers and AHRI Standard 1060, Rating Air-to-Air Energy Recovery Ventilation Equipment. Cassettes shall be listed in the AHRI Certified Products.
4. Unit shall include 2 inch thick, pleated panel outside air filters with an ASHRAE MERV rating of 8, upstream of the wheel on both exhaust and intake sides. Hinged service access door shall allow access to the wheel.

P. Polymer Energy Recovery Wheels:
1. Shall be provided with removable energy transfer matrix. Wheel frame construction shall be a welded hub, spoke and rim assembly of stainless, plated and/or coated steel and shall be self-supporting without matrix segments in place. Segments shall be removable without the use of tools to facilitate maintenance and cleaning. Wheel bearings shall be selected to provide an L-10 life in excess of 400,000 hours. Rim shall be continuous rolled stainless steel and the wheel shall be connected to the shaft by means of taper lock
2. All diameter and perimeter seals shall be provided as part of the cassette assembly and shall be factory set. Drive belts of stretch urethane shall be provided for wheel rim drive.
3. Energy recovery wheels shall be coated with silica gel desiccant permanently bonded by a process without the use of binders or adhesives, which may degrade desiccant performance. The substrate shall be lightweight polymer and shall not degrade nor require additional coatings for application in marine or coastal environments. Coated segments shall be washable with detergent or alkaline coil cleaner and water. Desiccant shall not dissolve nor deliquesce in the presence of water or high humidity.

Q. Aluminum Energy Recovery Wheels:

1. Unit shall contain a factory mounted and tested monolithic aluminum energy recovery wheel with an inverter duty motor and a durable segmented link drive belt composite. Wheel frame shall be constructed with prime G90 hot-dip galvanized steel tested for corrosion resistance of 400 hours of salt spray.
2. Energy recovery wheels shall be made of corrugated aluminum with a 3A molecular sieve desiccant coating. Coated segments shall be cleanable with hot water or air without degrading the latent recovery.
3. Unit shall include energy recovery wheel defrost control which includes an adjustable temperature sensor and timer wired to periodically stop the wheel rotation, which allows the warm exhaust air to defrost the wheel.
4. Unit shall include energy recovery wheel rotation detection sensors and a set of normally open and normally closed contracts for field indication of wheel rotation.
5. Energy recovery wheel shall include field adjustable mechanical purge. Purge shall be capable of limiting Exhaust Air Transfer Ratio (EATR) values to less than 1% through proper fan and purge adjustment.

R. Cross-Flow Fixed Plate Energy Recovery: As indicated on schedules on Drawings.

1. Unit shall contain a factory installed and tested cross-flow fixed plate energy recovery heat exchanger with no moving parts and unique rectangular flute design for low pressure drop values and enhanced performance.
2. Cross-flow fixed plate energy recovery heat exchanger shall be listed in the AHRI Certified Product Directory and bear the AHRI Certified Product Seal. Sensible, latent and total effectiveness along with pressure drop, EATR and OACF rating shall be clearly documented with performance tests conducted in accordance with ASHRAE Standard 84-91 and ARI Standard 1060-2011. Performance data derived from laboratory testing on heat exchanger conditions is in accordance with ASHRAE Standard 84-1991 “method of testing air-to-air heat exchangers.” Performance shall be rated in accordance with AHRI testing procedures.
3. Enthalpy cross-flow fixed plate energy recovery heat exchanger shall transfer both sensible and latent energies between exhaust and outside air streams in a cross-flow arrangement. The enthalpy fixed plate exchanger media shall be impregnated with a RC134 polymeric desiccant. The hydroscopic polymer shall exchange water by direct vapor transfer using molecular transport without the need of condensation. Desiccant shall be bactericide. The enthalpy fixed plate exchanger shall be capable of operating at temperatures between -40°F and 140°F. The enthalpy fixed plate exchanger shall be able to withstand, without more than 10% increase of pressure drop, pressure differential of at least 5” w.g. It shall withstand pressure differential of 10” w.g. without permanent deformation. The enthalpy cross-flow fixed plate energy recovery heat exchanger shall have both its membrane and complete assembly certified per the UL723 standard (fire and smoke development). Exhaust Air Transfer ratio (EATR), shall be less than 5%
4. The cross-flow fixed plate energy recovery heat exchanger shall be an Underwriters Laboratories Recognized Component for electrical and fire safety.
5. Unit shall include 2 inch thick, pleated panel outside air and exhaust filters with an ASHRAE MERV rating of 8, upstream of the heat exchanger.

S. Controls:
1. Factory Installed and Factory Provided Controller:
    a. Factory mount and wire 24 volt control system complete with required transformers and fusing.
    b. Controls shall prevent simultaneous operation of modes and shall enable operation in Dehumidification, Cooling, Heating or Economizer mode based on programmed settings
    c. Controls shall control based on dew point design settings for Dehumidification and Economizer modes, and sensible temperature settings for heating and cooling modes.
    d. Factory installed and wired sensors shall monitor Outdoor Air temperature, humidity and evaporator leaving air temperature.
    e. Supply air temperature sensor shall be furnished with unit.
    f. Modulating hot-gas reheat shall be enabled in dehumidification mode with modulation controlled by unit controls.
    g. System controls shall include anti-cycle timing and minimum compressor run/off times.
    h. Controller shall include preprogrammed test modes that permit operation in dehumidification, cooling, heating, or economizer test modes and facilitate complete start-up of unit mechanical and control components.
    i. Low voltage field wiring connections shall be made at factory installed low voltage terminal strip.
    j. Unit configuration, setpoint adjustment, sensor status viewing, unit alarm viewing, and occupancy scheduling shall be accomplished with factory controller integrated with a BACnet MS/TP network.
    k. Controller shall be capable of connection with other factory installed and factory provided unit controllers with individual unit configuration, setpoint adjustment, sensor status viewing, and occupancy scheduling available from a single unit. Unit controller shall be capable of controlling all features and options of the unit. Controller shall be factory installed in the unit controls compartment and factory tested.
    l. Controller shall be capable of standalone operation with unit configuration, set point adjustment, sensor status viewing, unit alarm viewing, and occupancy scheduling available without dependence on a building management system.
    m. Controller shall include non-volatile memory to retain programmed values, without the use of an external battery, in the event of a power failure.
    n. Unit shall be provided with a high condensate level switch that shuts down the unit when a high water level is detected in the drain pan.
    o. Variable Air Volume Controller:
        1) Unit shall utilize a variable capacity system and a variable speed supply fan system to modulate cooling and airflow as required to meet space temperature cooling loads and to save operating energy. Supply fan speed shall modulate based on supply air duct static pressure. Cooling capacity shall modulate based on supply air temperature.
        2) Unit shall modulate cooling and hot gas reheat as efficiently as possible, to meet space humidity loads and prevent supply air temperature swings and overcooling of the space.

3) Unit shall modulate heating based on space temperature or supply air temperature.

p. Constant Volume Controller:
1) Unit shall modulate cooling with constant airflow to meet space temperature cooling loads.
2) Unit shall modulate cooling and hot gas reheat as efficiently as possible, to meet space humidity loads and prevent supply air temperature swings and overcooling of the space.
3) Unit shall modulate heating capacity based on space temperature or supply air temperature.

q. Makeup Air Controller:
1) Unit shall modulate cooling with constant airflow to meet ventilation outside air loads. Cooling capacity shall modulate based on supply air temperature.
2) Unit shall modulate cooling and hot gas reheat as efficiently as possible, to meet outside air humidity loads and prevent supply air temperature swings and overcooling of the space.
3) Unit shall modulate heating based on supply air temperature or space temperature.

2.3 ROOF CURB

A. Provide factory supplied roof curb, 18 gauge perimeter made of zinc coated steel with supply and return air gasketing and wood nailer strips, designed to match roof slope. Ship knocked down and provided with instructions for easy assembly.

B. Curb shall be manufactured in accordance with the National Roofing Contractors Association guidelines.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for piping, ducts, and electrical systems to verify actual locations of connections before equipment installation.

C. Examine roof curbs and equipment supports for suitable conditions where units will be installed.

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

3.2 INSTALLATION

A. Comply with manufacturer's rigging and installation instructions for unloading units and moving to final locations.

B. Curb Support: Install roof curb on roof structure according to "The NRCA Roofing Manual."

1. Install and secure units on curbs and coordinate roof penetrations and flashing with roof construction.
2. Coordinate size, installation, and structural capacity of roof curbs, equipment supports, and roof penetrations.
3. Coordinate size, location, and installation of unit manufacturer's roof curbs and equipment supports with roof Installer.

C. Comply with requirements for gas-fired furnace installation in NFPA 54, "National Fuel Gas Code."

D. Install separate devices furnished by manufacturer and not factory installed.

E. Install new filters at completion of equipment installation and before testing, adjusting, and balancing.

F. Install drain pipes from unit drain pans to sanitary drain.

3.3 CONNECTIONS

A. Where installing piping adjacent to units, allow space for service and maintenance.

B. Gas Piping Connections:

1. Connect gas piping to furnace, full size of gas train inlet, and connect with union, pressure regulator, and shutoff valve with sufficient clearance for burner removal and service.
2. Install AGA-approved flexible connectors.

C. Hydronic Piping Connections:

1. Install shutoff valve and union or flange on each supply connection and install balancing valve and union or flange on each return connection.

D. Duct Connections:

1. Drawings indicate the general arrangement of ducts.
2. Connect ducts to units with flexible duct connectors.

E. Electrical Connections: Comply with requirements for power wiring, switches, and motor controls in Division 26.

1. Install electrical devices furnished by unit manufacturer but not factory mounted.

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. Inspect units for visible damage to furnace combustion chamber.
3. Perform the following operations for both minimum and maximum firing and adjust burner for peak efficiency
    a. Measure gas pressure at manifold.
    b. Measure combustion-air temperature at inlet to combustion chamber.
    c. Measure flue-gas temperature at furnace discharge.
    d. Perform flue-gas analysis. Measure and record flue-gas carbon dioxide and oxygen concentration.
    e. Measure supply-air temperature and volume when burner is at maximum firing rate and when burner is off. Calculate useful heat to supply air.
4. Verify operation of remote panel including pilot-light operation and failure modes. Inspect the following:
    a. High-limit heat exchanger.
    b. Alarms.
5. Inspect units for visible damage to refrigerant compressor, condenser and evaporator coils, and fans.
6. Start refrigeration system when outdoor-air temperature is within normal operating limits and measure and record the following:
    a. Cooling coil leaving-air, dry- and wet-bulb temperatures.
    b. Cooling coil entering-air, dry- and wet-bulb temperatures.
    c. Condenser coil entering-air dry-bulb temperature.
    d. Condenser coil leaving-air dry-bulb temperature.
7. Simulate maximum cooling demand and inspect the following:
    a. Compressor refrigerant suction and hot-gas pressures.
    b. Short-circuiting of air through outside coil or from outside coil to outdoor-air intake.
8. Inspect casing insulation for integrity, moisture content, and adhesion.
9. Verify that clearances have been provided for servicing.
10. Verify that controls are connected and operable.
11. Verify that filters are installed.
12. Clean coils and inspect for construction debris.
13. Clean furnace flue and inspect for construction debris.
14. Inspect operation of power vents.
15. Purge gas line.
16. Inspect and adjust vibration isolators
17. Verify bearing lubrication.
18. Clean fans and inspect fan-wheel rotation for movement in correct direction without vibration and binding.
19. Adjust fan belts to proper alignment and tension.

20. Start unit.
21. Inspect and record performance of interlocks and protective devices including response to smoke detectors by fan controls and fire alarm.
22. Operate unit for run-in period.
23. Calibrate controls.
24. Adjust and inspect high-temperature limits.
25. Inspect outdoor-air dampers for proper stroke
26. Verify operational sequence of controls.
27. Measure and record the following airflows. Plot fan volumes on fan curve.
    a. Supply-air volume.
    b. Return-air flow.
    c. Outdoor-air flow.

B. After startup, change filters, verify bearing lubrication, and adjust belt tension.

C. Remove and replace components that do not properly operate and repeat startup procedures as specified above.

D. Prepare written report of the results of startup services.

3.5 ADJUSTING

A. Adjust initial temperature and humidity set points.

B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

END OF SECTION

SECTION 23 74 43

OUTDOOR, SEMI-CUSTOM AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: Packaged, outdoor, central-station air-handling units (rooftop units) with the following components and the following accessories:
   1. Rooftop Custom Fan Wall Air Handling Units.
   2. Supply and Return Fans.
   3. Economizer outdoor- and return-air damper section.
   4. Factory Mounted VFD.
   5. Integral controls.
   6. Roof curbs.

1.2 DEFINITIONS

A. Outdoor-Air "Outdoor air" is defined as the air outside the building or taken from outdoors and not previously circulated through the system.

B. AHU: Rooftop Air Handling unit. As used in this Section, this abbreviation means custom outdoor, central-station air-handling units. This abbreviation is used regardless of whether the unit is mounted on the roof or on a concrete base on ground.

C. Supply-Air Fan: The fan providing supply-air to conditioned space. "Supply air" is defined as the air entering a space from air-conditioning, heating, or ventilating apparatus.

D. VVT: Variable-air volume and temperature.

1.3 ACTION SUBMITTALS

A. Product Data: Include manufacturer's technical data for each AHU, including rated capacities, dimensions, required clearances, characteristics, furnished specialties, and accessories.
   1. Product Data shall indicate dimensions, weights, capacities, ratings, fan performance to include fan curves, motor electrical characteristics to include motor technical data sheets, coil capacities to include performance printouts with pressure drops (water & air), vibration isolation, filter data sheets to include pressure drops, gauges and finishes.

B. 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.

1. Shop Drawings shall indicate assembly weights, unit dimensions, required clearances, construction details, shipping splits, maintenance clearances and field connection details.

C. Wiring Diagrams: Power, signal, and control wiring.

D. Samples for Initial Selection: For metal panel indicated with factory-applied finishes.

1.4 INFORMATIONAL SUBMITTALS

A. Field quality-control test reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and maintenance data, including installation and start-up data.

B. Include instructions for rigging, lifting, bearing lubrication, filter replacement, motor and drive replacement, and wiring diagram.

C. Include a recommended spare parts list customized to each unit complete with appropriate tag number, serial and / or part numbers along with a description to clearly identify the items.

1.6 QUALITY ASSURANCE

A. ASHRAE Compliance:
1. Comply with ASHRAE 15 for refrigerant system safety.
2. Comply with ASHRAE 33 for methods of testing cooling and heating coils.
3. Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
4. Applicable requirements in ASHRAE/I ESNA 90.1, Section 6 -"Heating, Ventilating, and Air-Conditioning."

B. Codes and Standards: Comply with requirements of the following:
1. AMCA 99 – Standards Handbook
2. AMCA 210 – Laboratory methods of testing fans for rating purposes. Unit to bear AMCA Certified Rating Seal.
3. AMCA 300 – test code for sound rating air moving devices.
4. AMCA 310
5. AMCA 500
6. Units to bear AMCA certified sound rating.
7. ANSI/AFBMA 9 Load rating and fatigue life for ball bearings.
8. ANSI/UL 900 test performance of air filter units.
9. ARI 410 for coils.

C. NFPA Compliance: Comply with NFPA 90A and NFPA 908.

D. UL Compliance: Comply with UL 1995.

E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.7 DELIVERY, STORAGE & HANDLING:

D. Unit shall ship with all openings securely covered with wood and / or nylon reinforced plastic wrap and to be watertight and securely strapped down on an open flatbed truck.

E. Units must be stored in a clean dry area and protected from the weather and construction traffic. Carefully follow manufacturers' storage instructions if installation does not immediately follow arrival at the job site.

F. Follow manufacturers rigging guidelines for movement and installation of equipment.

1.8 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

B. Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

1.9 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to replace components of AHU's that fail in materials or workmanship within specified warranty period.

B. Warranty Period for Control Boards: Manufacturer's standard, but not less than three years from date of Substantial Completion.

C. Unit manufacturer to warrant its product to be free of defects in materials and workmanship for a period of 24 months from date of substantial completion and 3 year warranty on fans and motors, to include all labor and rigging. Equipment found to be defective should be replaced or repaired to include all parts and labor. Component parts that require periodic replacement due to normal wear such as filters, fan belts, etc. are not covered by the warranty.

PART 2 - PRODUCTS

2.4 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Huntair, a CES Group Brand.
   2. Temtrol.
   3. Trane.
   4. York/JCI.

B. Alternate manufacturers seeking approval shall submit a complete submittal confirming compliance with specification, schedule and details.
   1. Include a copy of this specification section with line by line indication whether the proposed substitution complies, does not comply or provides an alternate method of compliance for consideration for prior approval.

2.5 OUTDOOR AIR-HANDLING UNITS, GENERAL

A. Unit shall be completely factory assembled and tested prior to shipment and shall have the approval of one of the following agencies: Underwriters' Laboratories (UL) or Electrical Testing Laboratories (ETL). The air handler shall bear an appropriate label certifying that the unit has been designed and manufactured in strict accordance with the UL 995 Standard for air handling equipment. If the manufacturer cannot provide an ETL/UL sticker on the air handler, it will be the sole responsibility of the Contractor to arrange for local ETL or UL approval and labeling.

B. The Unit Electrical Panel(s) shall be built in strict accordance to NEC Standards and shall bear an appropriate label certifying compliance with UL Standard 508A.

C. The air handling equipment manufacturer shall provide single source responsibility for all components for the unit whether specifically manufactured by the unit manufacturer or obtained outside and installed in the equipment.

2.6 CASING

A. General Fabrication Requirements for Casings: Formed and reinforced double-wall insulated panels, fabricated to allow removal for access to internal parts and components, with joints between sections sealed.

B. Casing Construction:
   1. Walls and roof to be (4") "Double Wall" construction as indicated in the specification for each section of the unit.
   2. Cabinet is a minimum 16-gauge A60 galvanized outer panel and a minimum 20-gauge G90 galvanized, inner liner for double walls.

3. Panels to be of standing seam construction with seams turned outward to provide a smooth flush interior.
4. Panels to be screwed or bolted together on maximum 8” centers with minimum 5/16” zinc plated screws or bolts sealed with a continuous bead of 3M540 caulking applied between the matching panel seams prior to assembly, and with a final bead following assembly on both the exterior and interior panel seams to produce an air tight unit.
5. Wall to base skin and wall to roof panel seams shall be continuously caulked to ensure leak-proof integrity of the unit housing.
6. AHU unit housing shall be constructed to prevent conditioned air bypass or mitigation through unit walls, roof and floor around any interior partition or component blank-off walls such as for filters, coils or fan bulkheads.

C. Floor: 0.125” thick steel tread plate floor material with polyurethane foam insulation and 20ga. G90 galvanized base under liner.

D. Insulation: Wall & Ceiling panels to be insulated as follows:
1. Solid liner: Fiberglass insulation with a thermal conductivity (k) of .26 $Btu{\cdot}in/(hr{\cdot}ft2{\cdot}°F)$ @ 75 °F mean temperature.
2. Perforated Liner in Supply fan and discharge section: Fiberglass mat-faced insulation with a thermal conductivity (k) of .23 $Btu{\cdot}in/(hr{\cdot}ft2{\cdot}°F)$ @ 75 °F mean temperature.

E. Interior Liners: Minimum 20-gauge G90 solid (perforated in Supply fan and discharge section) metal throughout the unit for the walls and roof. A finish bead of caulking will be applied between the liner and the interior panel seams to completely seal the panel.

F. Roof Panels: Weatherproof units shall be constructed with raised seams. Raised Roof Seams to be sealed between sandwiched panels with a bead of silicone caulking. The top of each roof panel seam is to receive a final bead of caulking and be sealed with a 16-gauge roof cleat mechanically formed to enclose the standing seam at the roof panel to panel joint. Roof to slope from center axis of roof to sides a minimum 1/8” per foot to allow complete water drainage and preclude standing water. Roof panels to overlap the side panels a minimum 1” all around unit creating an overhang to reduce direct runoff from the roof down over the side panels. All doors and louvers shall have a formed rain shield extending a minimum of 1” from the wall to direct water away from the door and louver openings.

G. Stiffeners of angle steel shall be supplied as required to maintain a casing deflection criteria of 1/100 at 1.5 times the working pressure.

H. Condensate Drain Pans: Formed sections of stainless-steel sheet, a minimum of 2 inches deep, and complying with ASHRAE 62.1.
1. Drain pans shall be composite plastic of 304 Stainless Steel double-wall construction with solid welded seams for complete water capture and containment.
2. Pans shall be provided under each horizontal row of cooling coils and shall extend a minimum 12” past the leaving face of the coil in direction of airflow.

3. Headers and return bends shall be located over the drain pan for collection of all condensate forming on headers and return bends.
4. Coils shall be easily removable without cutting or removing any portion of the drain pan.
5. Pans shall be insulated between the liner and the main pan. Pans shall be IAQ Double Sloping to a single drain.
6. Drain connection shall be a minimum 1-1/4” diameter MIPS thread extending out through the channel base where indicated on the Drawings.
7. Pans shall be provided for cooling coils, outside air intakes and under other components as required.

2.7 ACCESS DOORS

A. Access doors shall be double wall construction with G-90 galvanized interior panel.

B. Door jamb and frame shall be constructed of extruded aluminum with continuously welded corners for rigidity.

C. Door panels shall be insulated with expandable urethane foam insulation completely encapsulated and sealed between the door panels and frame.

D. Provide doors located and sized to allow for routine maintenance including motor replacement and filter replacement, electrical components and any other sections or components requiring access or maintenance.

E. Provide test ports in all doors into air tunnel.

F. Doors shall be provided with a minimum (2) dual acting heavy duty composite latches through 48” high, (3) latches through 72” high.

G. Latches shall be operable from both the interior and exterior of the unit.

H. Door hinge shall be stainless steel heavy duty self aligning. Door shall be sealed with continuous hollow closed cell foam gasket.

I. Doors to be provided with a dual high performance closed cell replaceable EPDM Sponge Rubber Seal around the entire perimeter of the door / frame.

J. Doors shall open against static pressure.

K. Doors used to access rotating equipment shall be provided with an OSHA approved safety latching mechanism and shall also have a highly visible, permanently fixed, caution sign on the exterior of the door.

L. Doors with access to moving parts must meet current UL mechanical protection guidelines.

M. Standard door size shall be 24” wide by 60” high unless restricted by height or section width.

N. Doors shall be provided with double pane wire reinforced glass viewing windows as called out for on the unit drawings in the specifications. Minimum window size to be 9” x 9” with 12” x 12” provided door size permitting.

2.8 BASES

A. Unit bases shall be constructed from structural steel channel iron or tubing around the entire perimeter of the unit and provided with intermediate structural tubing, channel and angle iron as required to support all internal components. All tubing, channel and angle joints shall be solid welded. Bolted or formed channel bases are not acceptable.

B. Base shall be provided with removable lifting lugs minimum, properly located to assure uniform loading. Maximum spacing between lifting lugs shall be 120”.

C. Units to be structurally designed to set on structural steel (supporting perimeter and across demounts) or Roof curbs as indicated on Drawings. Provide 12” high roof curbs where indicated.

D. Large openings (greater than one square foot) in the floor, including dampers openings, shall be covered with a removable powder coated heavy gauge steel grating bolted in place suitable for walking on which will prevent any personnel and large objects from falling through into the space below. Grating shall be capable of supporting minimum 300 pounds.

2.9 UNIT FINISHES

A. Exterior wall, roof, and the base structure and the interior floor, grating over floor openings, electrical panels, and inlet cones on the fans shall be powder coated with a lead- and cadmium-free polyester TGIC coating.

B. The interior floor, grating over floor openings, electrical panels, and inlet cones on the fans are to be individually coated & baked following shearing, notching, punching, & forming to provide 100% powder coverage over the entire finished piece to include the interior, exterior, and all metal edges.

C. The coating process is to be completed prior to assembly of the unit to ensure all joined surfaces are covered. Spray or brush applied coatings on the exterior of the cabinet only are not acceptable.

D. Powder Paint to have passed Salt Spray Resistance Test ASTM B 117-90 Minimum 1,000 Hours, Impact Test ASTM D 2794-90 up to 160 lbs and Humidity Resistance Test ASTM D 2247-87 Minimum 1000-hour test w/ maximum blister 1/16 in/1 mm.

   1. Color: As selected by Architect / Owner from manufacturer’s complete line.

2.10 FANS

A. Fans shall be aluminum airfoil, Class III, direct drive arrangement and shall be individually housed. Fans shall be certified by AMCA for performance. Fan shall be housed in a “cell”.

B. The quantity of supply and return fans indicated on the schedule is the Minimum and the motor horsepowers scheduled are the Maximum.

C. Fan housing or “cell” shall be constructed of aluminum or stainless steel with perforated inner liner, insulation, with either solid or perforated outer panels as required by applications.

D. Fan/motor shall be mounted within the housing on an adjustable slide rail base. Fan/motor assembly must be capable of either horizontal or vertical application.

1. Each fan/motor assembly shall be dynamically balanced to meet AMCA standard 204-96, for fan application class BV-5, to meet or exceed a rotational imbalance Grade .55, producing a maximum rotational imbalance of .022” per second peak, filter in (.55mm per second peak, filter in). “Filter in” measurement indicates that the specified balance grade must be achieved at the submitted design operating speed for the fan(s).
2. Fan and motor assemblies submitted for approval incorporating larger that 215T frame shall be balanced in three orthogonal planes to demonstrate compliance with the G.55 requirement with a maximum rotational imbalance of .022” per second peak filter in (.55 mm per second peak, filter in). Provide factory balance report with units demonstrating compliance to specified balance criteria.
3. Fan and motor assemblies shall be designed for application in multiple fan arrays.
4. Provide Motor removal rails.
5. Fan Backdraft Dampers
6. Each fan applied in multiple fan applications shall be provided with an integral back flow prevention device that automatically (without actuator, mechanical means or weights) prohibits recirculation of air in the event a fan, or fans, become disabled. The system effect for the submitted back flow prevention device shall be included in the calculation to determine the fan TSP for fan selection purposes and shall be indicated as a separate line item SP loss in the submitted fan selection data.
7. Manufacturers other than the basis of design being submitted must provide independent lab certification of fan testing that indicates the system effects attributed to the submitted back flow prevention device in the submitted close coupled mounting arrangement at the inlet of the fan. Fans submitted with discharge dampers or manually installed blank-off plates will not be approved.
8. Back Draft Damper performance data that is based on an AMCA ducted inlet and ducted discharge mounting configuration will not be accepted. Submitted Back flow prevention device data must be reflective of close coupled mounting at the intake of the fan(s) per the project design documents. Motorized dampers or other motorized devices submitted for back flow prevention are not acceptable.

9. AHU Manufacturers that do not manufacture the fans being submitted must provide tested and certified performance data for fans as installed in the AHU unit including the back draft damper system effects introduced by close coupled back draft dampers at the fan inlet.

2.11 FAN AIRFLOW MONITORING

A. Each fan shall be supplied with a complete flow measuring system, which indicates airflow in CFM. The flow measuring system shall utilize non-invasive, zero pressure drop flow analog output pressure sensing taps installed in the fan inlet cone for airflow monitoring capability. Provide CFM display and output signal to BAS.

2.12 MOTORS

A. Fan Motor: Comply with requirements in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."

B. All motors shall be standard foot mounted type, TEFC or TEAO motors selected at the specified operating voltage, RPM, and efficiency.

C. Motors shall meet the requirements of NEMA MG-1 Part 30 and 31, section 4.4.2.

D. Motors shall be manufactured by Baldor, Siemens or Toshiba. Motors shall be available in ½ HP increments as nameplate HP ratings from 1.5 HP through 12 HP.

2.13 ACOUSTICAL PERFORMANCE

A. The AHU unit shall provide the specified acoustical performance as scheduled on the drawings for the unit supply discharge opening(s), RA opening(s), and the Outside air and Exhaust air opening(s).

B. Coplanar silencer(s) and/or sound attenuator(s) shall be provided. Sound attenuator cross sectional area shall be selected to not exceed 500 fpm. Losses from sound attenuating devices must be included in the fan performance selection.

C. Manufacturer must provide modeled acoustical performance of the AHU unit.

D. Sound and performance data for approval showing only single fan performance for multiple fan array supplication is not acceptable and will be returned without review.

E. Any proposed remedy for deviations in submitted sound power levels shall be approved by a registered acoustical consultant as selected by the owner or architect. Costs for review of the proposed changes shall be borne by the contractor.

2.14 FAN ARRAY ELECTRICAL

A. Overview:

1. Provide a complete electrical system required to run the fan array system including all equipment, material, electrical enclosures, electrical components and electrical labor.
2. Fan array Electrical designs shall be in accordance with the NEC, UL 508A and local codes.

2.15 MOTOR CIRCUIT PROTECTION:

A. All motors in the fan array shall be provided with individual Motor Protection for thermal overload protection. All motor circuit protectors shall be located in VFD enclosure.

1. Multi-drive variable frequency drive control:
   a. Each supply and return fan shall be controlled by an individual ABB Variable Frequency drive. VFD's shall be installed in a NEMA 4 enclosure, ventilated by conditioned air, which is then EXHAUSTED from AHU. The Variable Frequency Drives shall be sized accordingly to start and hold each motor in the fan array. Provide short circuit protection through means of fuses with fuse block disconnects or other means of protection.
   b. The Supply Fan Variable Frequency Drives shall be mounted in a dedicated enclosure for connection to the AHU single point 460V power, including main disconnect. A separate Return Fan Variable Frequency Drive enclosure shall be provided with a main disconnecting means. AHU manufacturer to wire from Single point connection to the Return VFD panel so there is a single 460V connection required to AHU. Provide appropriate cooling of both enclosures.
   c. Motor circuit protectors shall be used for each motor in the fan array. Motor circuit protectors shall be housed and mounted in the VFD enclosure as required. Variable Frequency Drive enclosure and remote Motor circuit protector enclosure must be mounted at a minimal distance from fan array motors and each other.
   d. Provide three phase power distribution wiring and control wiring as required. All three phase power components shall have a rating listed for Short Circuit Current Rating. Provide control wiring and components required for complete operation of the fan array system.

B. Shaft Grounding – Isolated Bearings:

1. Provide either a shaft grounding system or Isolated bearings for each AC motor to prevent electrical damage to motor bearings and extend motor life by safely channeling harmful shaft currents to ground.

2.16 COILS

A. Chilled Water coils shall be of the microchannel type with aluminum plate ripple fin .008", extended surface rated in accordance with ARI 410 for water.

B. The tubes shall have a minimum .020" wall thickness of seamless copper expanded into the fin collars to provide a permanent mechanical bond. No metallic or thermal bonding materials are acceptable.

C. Return Bends shall be a minimum of one tube thickness greater than the main tubes (0.25) brazed replaceable copper. "U" type shaped tubes is not acceptable.

D. Coil headers shall be non-ferrous seamless Copper (cast iron headers are not acceptable), and provided with Schedule 40 Red Brass male pipe connections. Pipe connections shall be same end connections.

E. Each Coils supply & return connections shall be raised / lowered a minimum 6" from the bottom / top of the coil to allow room for piping connection hookup within the vestibule.

F. Each coil shall be provided with capped ½" brass vent & drain connections.

G. Coils shall be fully drainable with no trapped tubes. Coils shall be counter flow design with connections either left or right hand as specified. The use of internal restrictive devices such as turbolater springs or ribbons to obtain turbulent construction is not acceptable.

H. Coil casings shall be minimum 16 gauge 304 Stainless Steel, with formed 3/4" flanges on all sides of the coil with the tube sheets having pressed or extruded tube holes. The coil casing shall be reinforced so that the maximum unsupported length is 60". The reinforcements shall be of the same material as the casing.

I. Both ends of the coil to be sealed off from the main air stream by full height blank offs on both the entering air and leaving air sides. Blank offs to be the same material as the coil casing.

J. Headers and return bends to be further insulated with a closed cell neoprene gasket the full height & width of the coil casing to reduce condensation.

K. All coils are tested and rated in accordance with the Air Conditioning and Refrigeration Institute (ARI) Standard 410 and certified in accordance with the ARI certification program. All tubes shall be tested at a minimum 450 PSIG and all assemblies tested under water at 450 PSIG for a minimum of 5 minutes and rated for 450 PSIG working pressures. Individual tube and core tests before installation of header are not considered satisfactory. Hydrostatic tests alone will not be acceptable.

L. Coil Supply & Return piping connections extending through the cabinet wall shall be sealed by steel escutcheon plates. The escutcheon plate shall have a rolled collar around the pipe opening to protect the pipe and be equipped with an "O" ring rubber gasket between the collar and the pipe to prevent chaffing and provide an air tight seal around the opening.

2.17 AIR FILTRATION

A. Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

B. Filters shall be arranged for Face side loading. Face loading to be in gasketed Universal Holding Frames. The filter rack assemblies to blanked off to the sides, roof and floor and properly sealed to minimize filter bypass.

C. The Prefilter Section shall be factory fabricated as an integral part of the air handling unit. Filters to be arranged for face loading into a gasketed Universal holding frame. Filters to be 30 % Efficient, MERV-8 UL Class 2. (2) sets of the filters to be provided.

D. Second Filters, arranged for face loading into a gasketed positive sealing Universal Holding Frame to be 90 % Efficient, MERV-13 UL Class 2. (2) sets of filters to be provided.

E. Each filter bank to be provided with a differential pressure sensor in accordance with Section 23 09 23 "Instrumentation and Controls for HVAC."

F. Provide walk-in filter access sections upstream of each filter rack with adequate space for filter service.

G. Filter banks to be sized so maximum filter face velocity does not exceed 500 fpm.

2.18 LIGHTS/CONTROL WIRING

A. Provide vapor proof ormarine type LED light fixtures in each accessible section (quantity in each section to be as shown on Drawings) complete with a protective metal cage and sealed glass enclosure.

B. Lights to be wired to a common switch mounted in a weatherproof box adjacent to the fan access door complete with a duplex convenience outlet, 115-V, ground-fault-interrupter type with 20A overcurrent protection. Power shall be 120v/1/60.

C. All wiring to lights, switches and outlet(s) shall be in conduit and internal to the unit. No external conduit runs for the lights are allowed.

D. Junction boxes shall be furnished at unit splits to allow the electrical contractor to make final connections in the field. Wiring to be clearly labeled at junction points to facilitate reconnection.

E. Lights and convenience outlets shall be on an electrical circuit separate from the fan arrays, controls, and other operation related items.

2.19 LOUVERS

A. Provide exhaust louvers of the stationary drainable blade type with a drain gutter in each blade and downspouts in the frame jambs and mullions. The stationary blades shall be contained within a 6" Steel Galvanized frame with 14 gauge galvanized bird screen included and contained within a removable frame.

B. Louver design shall incorporate structural supports to withstand a wind load of 20 lbs. per square foot (equivalent to a 90-mph wind).

C. Published louver performance data must be submitted for pressure drop.

D. Outside Air Louvers shall be RUSKIN EME6625D extruded Aluminum louvers. Louvers shall be stationary, drainable type with built-in downspouts and furnished with bird screen. Blades shall be vertical and housed within an aluminum frame mounted to the unit exterior.

2.20 LOUVER AIR FLOW MEASURING STATIONS

A. Refer to Drawings for additional details and requirements. Airflow monitoring stations are to be provided and installed at the factory by the air handling unit manufacturer. Interface with Building Automation System.

B. Each device shall be designed and built to comply with, and provide results in accordance with, accepted practice as defined for system testing in the ASHRAE Handbook of fundamentals, as well as in the Industrial Ventilation Handbook.

C. Approved Manufacturer: Ruskin model EAMP with Ruskin CD60 motorized damper or prior approved equal.

D. Provide an electronic thermal dispersion type airflow temperature measuring station (AFTMS).

1. AFTMS shall be capable of monitoring and reporting the airflow and temperature at each measuring location.
2. AFTMS shall consist of multiple measuring probes and sensor points and a control transmitter that communicates with the building automation system (BAS).

E. Probes shall be constructed of an airfoil shaped 6063T5 aluminum extrusion ensuring the lowest pressure drop and noise generation.

1. Individual probes shall include one or more sensor circuits encased in an UL 94 flame rated, high impact, ABS shroud.

F. Each sensor circuit shall consist of an epoxy coated ambient thermistor, an epoxy coated heated thermistor and a microprocessor mounted to a printed circuit board (PCB).

1. Sensor circuits shall be wired through a continuous, UL plenum rated, ribbon cable and secured through a PCB connector to ensure a rigid connection to the sensor circuit.

G. Soldering thermistor leads to loose wires is not an acceptable practice. Each sensor circuit shall terminate in a microprocessor-based multiplexer at the end of each probe.

H. Probe multiplexer shall digitally communicate the average airflow and temperature to the microprocessor-based control transmitter.

I. Analog signals between the probe and transmitter are unacceptable.

J. Readily available UL Plenum rated CAT5 communications cable with square terminal connectors, dust boot covers and gold plated contacts shall be utilized.

K. Communications cable shall be a minimum of ten feet in length and shall be available up to 50 feet if required.

L. Control transmitter shall be capable of processing up to 16 independent sensing points per airflow measuring location and shall operate on a fused 24 VAC supply.

M. Control transmitter shall feature a 16x2 character alphanumeric LCD display, digital offset/gain adjustment, continuous performing sensor/transmitter diagnostics and a visual alarm to detect malfunctions.

N. LCD shall be field adjustable to display either I.P or S.I. units.

O. Transmitter output shall be field adjustable 4-20 mA or 2-10 VDC.

P. AFTMS shall be in all respects equivalent to Ruskin model EAMP

2.21 DAMPERS

A. Control Dampers:
1. Provide Low Leak Dampers with published leakage data certified under the AMCA certified ratings program.
2. Low Leak Dampers shall be rated less than 10 cfm per sq. ft. of area at 4-in. w.g. pressure difference through a 48” x 48” damper.
3. Low leak dampers shall be fabricated of steel or aluminum with hat mounting flanges on both sides of the frame.
4. Blades shall be mechanically locked in extruded blade slots, yet be easily replaceable in the field. Adhesive or clip-on type blade seals are not acceptable. Bearings shall be non-corrosive molded synthetic.
5. Axles shall be square or hexagonal (round is not acceptable) to provide positive locking connection to blades and linkage. Linkage shall be concealed in the frame.

2.22 CONTROLS

A. Control equipment and sequence of operation are specified in Section 23 09 23 “Instrumentation and Controls Systems for HVAC.”

2.23 TEST PORTS

A. Provide 1” diameter test ports for unit air stream testing in each plenum section between each component within the AHU. Test ports shall have a tube that extends between the inside and outside of the unit and a screwed cap on the exterior to allow access. The test ports shall have been flanged on the exterior to allow air seal and shall be flanged on the interior to cover the penetration of the casing.

2.24 ROOF CURBS

A. Roof curbs with vibration isolators and wind or seismic restraints are specified in Section 23 05 48 "Vibration and Seismic Controls for HVAC Piping and Equipment." Refer to Drawings for which units require roof curbs. Air handling units with fans dynamically balanced to meet AMCA standard 204-96, for fan application class BV-5, to meet or exceed a rotational imbalance Grade .55 do not require spring isolation curbs.

B. Roof curbs are to be sloped to match roof slope.

C. Materials: Galvanized steel with corrosion-protection coating, watertight gaskets, and factory-installed wood nailer; complying with NRCA standards.

D. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 908.

E. Materials: ASTM C 1071, Type Ior II.

F. Thickness: 1-1/2 inches.

G. Wind and Seismic Restraints: Metal brackets compatible with the curb and casing, painted to match AHU RTU, used to anchor unit to the curb, and designed for loads at Project site. Comply with requirements in Section 23 05 48 "Vibration and Seismic Controls for HVAC Piping and Equipment" for wind-load requirements.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Roof Curb: Install on roof structure or concrete base, level and secure. Install AHUs on curbs and coordinate roof penetrations and flashing with roof construction specified in Section 07 72 00 "Roof Accessories." Secure AHUs to upper curb rail, and secure curb base to roof framing or concrete base with anchor bolts.

B. Unit Support: Install unit level on structural curbs. Coordinate wall penetrations and flashing with wall construction. Secure AHUs to structural support with anchor bolts.

C. Install wind and seismic restraints according to manufacturer's written instructions.

D. Install condensate drain, minimum connection size, with trap and indirect connection to nearest roof drain or area drain.

E. Duct installation requirements are specified in other Division 23 Sections. Drawings indicate the general arrangement of ducts. The following are specific connection requirements:
   1. Install ducts to termination at top of roof curb.
   2. Remove roof decking only as required for passage of ducts. Do not cut out decking under entire roof curb.
   3. Connect supply ducts to AHUs with flexible duct connectors specified in Section 23 33 00 "Air Duct Accessories."
   4. Install return-air duct continuously through roof structure.
   5. Install normal-weight, 3000-psi, compressive strength (28-day) concrete mix inside roof curb, 4 inches thick. Concrete, formwork, and reinforcement are specified with concrete.

3.2 STARTUP SERVICE

A. Provide factory start-up services and owner training for air handling units and VFD’s. Supplier to provide as many days as needed for complete start-up, including coordination with electrical/controls/test and balance contractors and participation in the commissioning process.

B. A factory authorized representative shall perform on-site inspections and instruction and be responsible for ensuring that the field assembly is acceptable to the manufacturer.

C. Unit shall be swept and vacuumed clean.

D. Complete installation and startup checks according to manufacturer’s written instructions.

E. Install new, clean filters.

3.3 FIELD QUALITY CONTROL

A. Complete the manufacturer's installation and startup checklists and resolve all discrepancies.

B. Provide the Commission Agent and Owner PM with the completed checklists/test results.

3.4 TRAINING

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

END OF SECTION

SECTION 23 81 23

COMPUTER-ROOM AIR-CONDITIONERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Floor-mounted computer-room air conditioners
   2. Ceiling-mounted computer-room air conditioners.
   3. Console Computer-room air conditioners

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include material descriptions, dimensions of individual components and profiles, and finishes.

B. Shop Drawings: For computer-room air conditioners. Include plans, elevations, sections, details, and attachments to other work.

C. Color Samples: For unit cabinet, discharge grille, and exterior louver and for each color and texture specified.

1.3 INFORMATIONAL SUBMITTALS

A. Seismic Qualification Certificates: For computer-room air conditioners, accessories, and components, from manufacturer.

B. Field quality-control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
   1. ASHRAE Compliance:
   2. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."

3. Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."
4. Applicable requirements in ASHRAE/IESNA 90.1.

1.6 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of computer-room air conditioners that fail in materials or workmanship within specified warranty period.
   1. Warranty Period for Compressors: Manufacturer's standard, but not less than five years from date of Substantial Completion.
   2. Warranty Period for Humidifiers: Manufacturer's standard, but not less than three years from date of Substantial Completion.
   3. Warranty Period for Control Boards: Manufacturer's standard, but not less than three years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Computer-room air conditioners shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

2.2 FLOOR-MOUNTED UNITS 6 TONS AND LARGER

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings:
   1. Liebert Corporation.
   2. APC
   3. Stultz

B. Alternate manufacturers seeking approval shall submit a complete submittal confirming compliance with specification, schedule and details. In addition provide a copy of this specification section with line by line indication whether the proposed substitution complies, does not comply or provides an alternate method of compliance for consideration for prior approval.

C. Description: Packaged, factory assembled, prewired, and prepiped; consisting of cabinet, fans, filters, humidifier, and controls.

D. Cabinet and Frame: Welded steel, braced for rigidity, and supporting compressors and other mechanical equipment and fittings.
   1. Doors and Access Panels: Galvanized steel with polyurethane gaskets, hinges, and concealed fastening devices.

2. Insulation: Thermally and acoustically insulate cabinet interior with 1-inch- thick duct liner.
3. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
4. Finish of Exterior Surfaces: Baked-on, textured vinyl enamel; color as selected from manufacturer's standard colors.
5. Floor Stand: Welded tubular steel, with adjustable legs and vibration isolation pads.

E. Supply-Air Fan(s):
1. Supply-Air Fan: The unit shall be equipped with plug fans: integral direct driven fans with backward-curved blades and electronically commutated DC motor. The fan speed shall be variable and automatically regulated by internal controls through all modes of operation. The fan shall have a dedicated motor, fault monitoring circuitry, and speed controller, which shall provide a level of redundancy. The impeller shall be made of aluminum and dynamically balanced. The EC fans shall be located within the unit. The EC fans shall also provide greater energy savings than forward curved centrifugal fan and variable speed drives.

F. Refrigeration System:
1. Compressors: Semi-hermetic reciprocating/scroll/screw/rotary with suction-gas-cooled, resilient suspension system, crankcase heater, manual-reset high-pressure switch, and pump-down low-pressure switch.
2. Refrigerant: R-407C or R-410A.
3. Refrigerant Evaporator Coil: Alternate-row or split-face-circuit, direct-expansion coil of seamless copper tubes expanded into aluminum fins.
   a. Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir.
4. Remote Air-Cooled Refrigerant Condenser: Corrosion-resistant cabinet, copper-tube aluminum-fin coils arranged for two circuits, multiple direct-drive propeller fans with permanently lubricated ball bearings, and single-phase motors with internal overload protection and integral electric control panel and disconnect switch. Control capacity by modulating fan speeds

G. Electric-Resistance Heating Coil: If required by the construction documents, provide an enclosed finned-tube electric elements arranged for minimum of three stages, with thermal safety switches, manual-reset overload protection, and branch-circuit overcurrent protection.

H. Refrigerant Heating Coil: If required by the construction documents, provide a Hot-gas coil of seamless copper tubes expanded into aluminum fins with three-way solenoid valve on first-stage refrigerant circuit.

I. Chilled Water Cooling Coil: If required by the construction documents, Provide dual cooling chilled water coil with integral 2-way modulating control valve.

J. Filter: The filter shall be an integral part of the system and located within the cabinet or in return air ductwork, if applicable. The filter shall be deep-pleated, 2 in thick with a MERV 13 rating efficiency based on ASHRAE 52.2-2007. A filter clog switch shall be included. Mesh type, cleanable filters shall be unacceptable.

K. Infrared Humidifier (If required by the construction documents):
1. The humidifier shall be of the infrared type, consisting of high intensity quartz lamps mounted above and out of the water supply or the cylinder type.
2. The evaporator pan shall be stainless steel and arranged to be serviceable without disconnecting water supply lines, drain lines, or electrical connections.
3. The complete humidifier section shall be pre-piped ready for final connection.
4. The infrared humidification system shall use bypass air to prevent over-humidification of the controlled space.
5. The auto flush system shall automatically flush deposits from the humidifier pan.
6. The system shall be field adjustable to change the cycle time to suit local water conditions.
7. A minimum 1 in. air gap within the humidifier piping assembly shall prevent back flow of the humidifier supply water.

L. Disconnect Switch:
1. A locking-type fused disconnect switch shall be mounted in the electrical panel and shall be capable of disrupting the flow of power to the unit.
2. The locking type shall consist of a main unit switch operational from outside the unit.
3. The electric panel compartment shall be accessible only with the switch in the Off position.
4. The locking disconnect shall be lockable in support of lockout/tagout safety programs.
5. The electrical panel shall provide at least 65,000A short-circuit current rating (SCCR).

M. Two-Way Motorized Ball Valve:
1. A two-way pre-piped motorized ball valve shall control the chilled water flow through the cooling coil.
2. The integral controls shall manage non-spring return the valve actuator movement to maintain the desired room conditions for various entering water temperatures.
3. Cooling capacity shall be regulated by varying the chilled water flow.
4. The maximum differential pressure across the closed valve shall be 200 PSI.

N. Control System:
1. The integral control system shall be microprocessor-based with a touchscreen display.
2. The display and housing shall be viewable while the front panel is open or closed.
3. The controls shall be menu-driven.

4. The system shall display user menus for active alarms, event log, graphic data, unit view/status overview (including the monitoring of room conditions, operational status in percentage of each function, date and time), total run hours, various sensors, display setup and service contacts.
5. A password shall be required to make system changes.
6. Service menus shall include setpoints, standby settings (lead/lag), timers/sleep mode, alarm setup, sensor calibration, maintenance/wellness settings, options setup, system/network setup, auxiliary boards, and diagnostics/service mode. Refer to points lists on drawings.
7. The integral controls shall be factory-set to allow precise monitoring and control of the condition of the air entering and leaving the unit.
8. This control shall include predictive methods to control air flow and cooling capacity based control sensors installed.
9. Proportional and Tunable PID shall also be user selectable options.
10. Each controller shall have one factory-supplied and connected supply air sensor that may be used as a controlling sensor or reference.
11. When multiple sensors are applied for control purposes, the user shall be able to control based on a maximum or average temperature reading.

O. BACnet Interface: Provide with open protocol BACnet interface with the JCI Metasys system serving the building. Assist JCI with mapping all points listed in the points list on the drawings.

2.3 FLOOR-MOUNTED UNITS 5 TONS AND SMALLER

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings:
1. Liebert Corporation.
2. APC
3. Stultz

B. Alternate manufacturers seeking approval must submit a complete submittal confirming compliance with specification, schedule and details. In addition provide a copy of this specification section with line by line indication whether the proposed substitution complies, does not comply or provides an alternate method of compliance for consideration for prior approval.

C. Description: Self-contained, factory assembled, prewired, and prepiped; consisting of cabinet, fan, filters, and controls; for vertical floor mounting in upflow or downflow configuration.

D. Cabinet and Frame:
1. Welded tubular-steel frame with removable steel panels with baked-enamel finish, insulated with 1-inch- thick duct liner.
2. Floor Stand: Welded tubular steel, with adjustable legs and vibration isolation pads.

E. Supply-Air Fan:

1. The unit shall be equipped with plug fans: integral direct driven fans with backward-curved blades and electronically commutated DC motor.
2. The fan speed shall be variable and automatically regulated by internal controls through all modes of operation.
3. The fan shall have a dedicated motor, fault monitoring circuitry, and speed controller, which shall provide a level of redundancy.
4. The impeller shall be made of aluminum and dynamically balanced.
5. The EC fans shall be located within the unit.
6. The EC fans shall also provide greater energy savings than forward curved centrifugal fan and variable speed drives.

F. Upflow Supply with Front Air Return:

1. The supply air shall exit from the top of the cabinet.
2. The return air shall be through the front factory installed grilles.
3. The EC fan shall be factory mounted in the upper portion of the unit. The fan shall be located to pull air through the filters and cooling coil to ensure even air distribution and maximum coil performance.
4. The unit shall be supplied with a ducted air discharge plenum. The plenum shall extend to above the ceiling (length as required) with top duct connection.

G. Downflow Supply with Top Air Return:

1. The supply air shall exit from the bottom of the cabinet.
2. The return air shall be through the top opening. The EC fans shall be factory mounted in the lower portion of the unit.
3. The fan shall be located to pull air through the filters and cooling coil to ensure even air distribution and maximum coil performance.

H. Refrigeration System:

1. Compressor: Hermetic, with oil strainer, internal motor overload protection, resilient suspension system, and crankcase heater.
2. Refrigeration Circuit: Low-pressure switch, manual-reset high-pressure switch, thermal-expansion valve with external equalizer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
3. Refrigerant: R-407C or R-410A.
4. Refrigerant Evaporator Coil: Direct-expansion coil of seamless copper tubes expanded into aluminum fins, with two circuits, each with solenoid valve.
    a. Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir.
5. Remote Air-Cooled Refrigerant Condenser: Integral, copper-tube aluminum-fin coil with propeller or centrifugal fan, direct driven.
6. Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.

I. Electric-Resistance Heating Coil:
   1. The reheat shall be a low-watt density 304/304 stainless steel finned-tubular electric reheat.
   2. The reheat section shall include UL/CSA recognized safety switches to protect the system from overheating.
   3. The electric reheat shall be controlled in two stages. The reheat elements shall be accessible from the right side of the cabinet

J. Refrigerant Heating Coil: Hot-gas coil of seamless copper tubes expanded into aluminum fins with three-way solenoid valve on first-stage refrigerant circuit.

K. Chilled Water Cooling Coil: Provide dual cooling chilled water coil with integral 2-way modulating control valve.

L. Filter: The filter shall be an integral part of the system and located within the cabinet. The filter shall be deep-pleated, 2 in thick with a MERV 13 rating efficiency based on ASHRAE 52.2-2007. A filter clog switch shall be included. Mesh type, cleanable filters shall be unacceptable.

M. Infrared Humidifier:
   1. The humidifier shall be of the infrared type, consisting of high intensity quartz lamps mounted above and out of the water supply.
   2. The evaporator pan shall be stainless steel and arranged to be serviceable without disconnecting water supply lines, drain lines, or electrical connections.
   3. The complete humidifier section shall be pre-piped ready for final connection.
   4. The infrared humidification system shall use bypass air to prevent over-humidification of the controlled space.
   5. The auto flush system shall automatically flush deposits from the humidifier pan.
   6. The system shall be field adjustable to change the cycle time to suit local water conditions.
   7. A minimum 1 in. air gap within the humidifier piping assembly shall prevent back flow of the humidifier supply water.

N. Disconnect Switch:
   1. A locking-type fused disconnect switch shall be mounted in the electrical panel and shall be capable of disrupting the flow of power to the unit.
   2. The locking type shall consist of a main unit switch operational from outside the unit.
   3. The electric panel compartment shall be accessible only with the switch in the Off position.
   4. The locking disconnect shall be lockable in support of lockout/tagout safety programs.
   5. The electrical panel shall provide at least 65,000A short-circuit current rating (SCCR).

O. Control System:
  1. The integral control system shall be microprocessor-based with a 9" minimum color touchscreen display.
  2. The display and housing shall be viewable while the front panel is open or closed.
  3. The controls shall be menu-driven.
  4. The system shall display user menus for active alarms, event log, graphic data, unit view/status overview (including the monitoring of room conditions, operational status in percentage of each function, date and time), total run hours, various sensors, display setup and service contacts.
  5. A password shall be required to make system changes.
  6. Service menus shall include setpoints, standby settings (lead/lag), timers/sleep mode, alarm setup, sensor calibration, maintenance/wellness settings, options setup, system/network setup, auxiliary boards, and diagnostics/service mode. Refer to points lists on drawings.
  7. The integral controls shall be factory-set to allow precise monitoring and control of the condition of the air entering and leaving the unit.
  8. This control shall include predictive methods to control air flow and cooling capacity based control sensors installed.
  9. Proportional and Tunable PID shall also be user selectable options.
  10. Each controller shall have one factory-supplied and connected supply air sensor that may be used as a controlling sensor or reference.
  11. When multiple sensors are applied for control purposes, the user shall be able to control based on a maximum or average temperature reading.

P. BACnet interface: Provide with open protocol BACnet interface with the JCI Metasys system serving the building. Assist JCI with mapping all points listed in the points list on the drawings.

2.4 CONSOLE UNITS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings:
  1. Liebert Corporation.

B. Description: Split system consisting of evaporator section for floor or wall mounting and remote condensing section.

C. Evaporator Cabinet: Furniture-grade steel with baked-enamel finish; with front access and containing direct-drive centrifugal fans and two-speed motor.
  1. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Condenser Cabinet: Steel with baked-enamel finish and containing compressor and condenser.

E. Refrigeration System:
   1. Compressor: Hermetic, with oil strainer, internal motor overload protection, resilient suspension system, and crankcase heater.
   2. Refrigeration Circuit: Filter/dryer, manual-reset high-pressure switch, thermal-expansion valve with external equalizer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
   3. Refrigerant: R-407C or R-410A.
   4. Refrigerant Evaporator Coil: Direct-expansion coil of seamless copper tubes expanded into aluminum fins.
   5. Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir where required.
   6. Remote Air-Cooled Refrigerant Condenser: Integral, copper-tube aluminum-fin coil with propeller or centrifugal fan, direct driven.
   7. Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.

F. Electric-Resistance Heating Coil: Finned-tube electric elements with contactor and high-temperature-limit switches.

G. Filter: 2-inch thick, disposable, glass-fiber media. MERV-13 (ASHRAE 52.2)

H. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.

I. Control System: Unit-mounted panel with contactors, control transformer with circuit breaker, and solid-state temperature-and humidity-control modules. Provide solid- state, unit-mounted control panel with start-stop switch, adjustable humidity set point, and adjustable temperature set point.

2.5 FAN MOTORS

A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."
   1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
   2. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26 Sections.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install computer-room air conditioners level and plumb, maintaining manufacturer's recommended clearances. Install according to ARI Guideline B.

B. Computer-Room Air-Conditioner Mounting: Install using Factory Floor Stand and elastomeric pads. Comply with requirements for vibration isolation devices specified in Division 23 Section 23 05 48 "Vibration and Seismic Controls for HVAC Piping and Equipment."

  1. Minimum Deflection: 1/4 inch

C. Suspended Computer-Room Air Conditioners: Install using continuous-thread hanger rods and spring hangers of size required to support weight of computer-room air conditioner.

  1. Comply with requirements for vibration isolation devices specified in Section 23 05 48 "Vibration and Seismic Controls for HVAC Piping and Equipment." Fabricate brackets or supports as required.
  2. Comply with requirements for hangers and supports specified in Section 23 05 29 "Hangers and Supports for HVAC Piping and Equipment."

D. Air-Cooled Refrigerant Condenser Mounting: Install using restrained spring isolators. Comply with requirements for vibration isolation devices specified in Section 23 05 48 "Vibration and Seismic Controls for HVAC Piping and Equipment."

  1. Minimum Deflection: 1/4 inch.

3.2 CONNECTIONS

A. Piping installation requirements are specified in other heating, ventilating, and air-conditioning Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to machine to allow service and maintenance.

C. Water and Drainage Connections: Comply with applicable requirements in Section 22 11 16 "Domestic Water Piping." Provide adequate connections for water-cooled units, condensate drain, and humidifier flushing system.

D. Refrigerant Piping: Comply with applicable requirements in Section 23 23 00 "Refrigerant Piping." Provide shutoff valves and piping.

3.3 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. Tests and Inspections:
   1. Inspect for and remove shipping bolts, blocks, and tie-down straps.
   2. After installing computer-room air conditioners and after electrical circuitry has been energized, test for compliance with requirements.
   3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Computer-room air conditioners will be considered defective if they do not pass tests and inspections.

D. Prepare test and inspection reports.

E. After startup service and performance test, change filters and flush humidifier.

END OF SECTION

SECTION 23 81 26

SPLIT-SYSTEM AIR-CONDITIONERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
  1. Split-system air-conditioning.
  2. Heat-pump units consisting of separate evaporator-fan.
  3. Compressor-condenser components.

1.2 ACTION SUBMITTALS

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

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
  1. Detail equipment assemblies and indicate, required clearances, method of field assembly, and location and size of each field connection.

1.3 INFORMATIONAL SUBMITTALS

A. Installer Qualifications: Certification documents for those technicians performing tasks involving refrigerants covered by Section 608 of the Clean Air Act.

B. Field quality control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70.

B. Standards Compliance:
  1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."
  2. Applicable requirements in ASHRAE 62.1, Section 4 "Outdoor Air Quality," Section 5 "Systems and Equipment," Section 6 " Procedures," and Section 7 - "Construction and System Start-up."

3. Applicable requirements in ASHRAE/IESNA 90.1
4. Furnish and install equipment and accessories in accordance with the International Mechanical Code.
5. Furnish and install equipment and accessories in accordance with the International Energy Conservation Code.
6. Units shall be listed in the applicable ARI Directory of Certified products
7. Handling of refrigerants and components containing refrigerants shall comply with Section 608 of the Clean Air Act.

1.6 WARRANTY

A. Warranty Period:
   1. For Compressor: Five year(s) from date of Substantial Completion.
   2. For Parts: Two year(s) from date of Substantial Completion.
   3. For Labor: Two year(s) from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Trane Company (Full size only)
   2. American Standard (Full size only)
   3. Daikin (Full size and mini-splits)
   4. York, Johnson Controls Unitary Products (Full size only)
   5. Mitsubishi Electric Trane (Mini-splits only)

2.2 INDOOR UNITS (5 TONS OR LESS)

A. Full-size Evaporator-Fan Components:
   1. Chassis: Galvanized steel with flanged edges, removable panels for servicing, and insulation on back of panel.
   2. Insulation: Faced, glass-fiber duct liner.
   3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 210/240.
   4. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
   5. Fan: Forward-curved, double-width wheel of galvanized steel; directly connected to motor.

6. Fan Motors:
   a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."
   b. Multi-tapped, multispeed with internal thermal protection and permanent lubrication.
7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
8. Condensate Drain Pans:
   a. Fabricated with one percent slope and 2 inches deep in at least two planes to collect condensate and to direct water toward drain connection.
   b. Single-wall, composite plastic or stainless steel. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.
9. General Requirements for Air Filtration Section:
   a. 2” thick factory-fabricated, viscous-coated, flat-panel type.
   b. Arrestance according to ASHRAE 52.1: 80.
   c. MERV-13 according to ASHRAE 52.2: 7
   d. Media: Interlaced glass fibers sprayed with nonflammable adhesive and antimicrobial agent.

B. Mini-split, Evaporator-Fan Components:
1. Cabinet: Enameled steel with removable panels on front and ends, and discharge drain pans with drain connection.
2. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 210/240.
3. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
4. Fan: Direct drive, centrifugal.
5. Fan Motors: Comply with Section 23 05 13 "Common Motor Requirements for HVAC Equipment." Provide multispeed, permanent lubrication.
6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
7. Condensate Drain Pans:
   a. Fabricated with one percent slope to direct water toward drain connection.
   b. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.
8. Air Filtration Section:
   a. Factory-fabricated, viscous-coated, flat-panel type.
   b. Arrestance according to ASHRAE 52.1: 80.
   c. MERV according to ASHRAE 52.2: 5
   d. Media: Interlaced glass fibers sprayed with nonflammable adhesive and antimicrobial agent.

2.3 OUTDOOR UNITS (5 TONS OR LESS)

A. Air-Cooled, Compressor-Condenser Components:

1. Casing: Steel, finished with baked enamel, with removable panels. Provide brass service valves, fittings, and gage ports on exterior of casing.
2. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation device. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
    a. Compressor Type: Scroll or rotary.
    b. Compressor motor with manual-reset high-pressure switch and automatic-reset low-pressure switch.
    c. Refrigerant Charge R-407C or R-410A.
    d. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and liquid subcooler. Comply with ARI 210/240.
3. Heat-Pump Components: Reversing valve and low-temperature-air cutoff thermostat.
4. Fan: Aluminum-propeller type, directly connected to motor.
5. Motor: Permanently lubricated, with integral thermal-overload protection.
6. Low Ambient Kit: Permits cooling operation down to 0 deg F.
7. Mounting Base: Concrete pad, 4 inches nominal thickness, extend 6 inches beyond all sides of equipment.

2.4 INDOOR UNITS (6 TONS OR MORE)

A. Concealed Evaporator-Fan Components:

1. Chassis: Galvanized steel with flanged edges, removable panels for servicing, and insulation on back of panel.
2. Insulation: Faced, glass-fiber duct liner.
3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.
4. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, automatic-reset thermal cutout, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
5. Fan: Forward-curved, double-width wheel of galvanized steel; directly connected to motor.
6. Fan Motors:
    a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."
    b. Multitapped, multispeed with internal thermal protection and permanent lubrication.
    c. Three-phase, permanently lubricated, ball-bearing motors with built-in thermal-overload protection.
    d. Wiring Terminations: Connect motor to chassis wiring with plug connection.

7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
8. Filters: 2 inch thick, fiberboard frames.
9. Condensate Drain Pans:
    a. Fabricated with two percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.
        1) Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
        2) Depth: A minimum of 2 inches deep.
    b. Single-wall, composite plastic.
    c. Single-wall, galvanizedstainless- with space between walls filled with foam insulation and moisture-tight seal where indicated on drawings.
    d. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on both ends of pan.
    e. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

B. Floor-Mounted, Evaporator-Fan Components:
1. Cabinet: Enameled steel with removable panels on front and ends in color selected by Architect.
    a. Insulation: Faced, glass-fiber duct liner.
2. Condensate Drain Pans:
    a. Fabricated with two percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.
        1) Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
        2) Depth: A minimum of 2 inches deep.
    b. Single-wall, composite plastic.
    c. Single-wall, stainless-steel sheet with space between walls filled with foam insulation and moisture-tight seal where indicated on drawings.
    d. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on both ends of pan.
    e. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.
3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.
4. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, automatic-reset thermal cutout, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
5. Fan: Direct drive, centrifugal.

6. Fan Motors:
    a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."
    b. Multitapped, multispeed with internal thermal protection and permanent lubrication.
    c. Enclosure Type: Totally enclosed, fan cooled.
    d. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.
    e. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 26.
7. Air Filtration Section:
    a. General Requirements for Air Filtration Section:
        1) Comply with NFPA 90A.
        2) Minimum MERV-13 according to ASHRAE 52.2.
        3) Filter-Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.

2.5 OUTDOOR UNITS (6 TONS OR MORE)

A. Air-Cooled, Compressor-Condenser Components:
1. Casing: Steel, finished with baked enamel in color selected by Architect, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
2. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation device. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
    a. Compressor Type: Scroll or rotary.
    b. Two-speed or variable speed compressor motor with manual-reset high-pressure switch and automatic-reset low-pressure switch.
    c. Refrigerant: R-407C or R-410A.
    d. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and liquid subcooler. Comply with ARI 206/110.
3. Heat-Pump Components: Reversing valve and low-temperature-air cutoff thermostat.
4. Fan: Aluminum-propeller type, directly connected to motor.
5. Motor: Permanently lubricated, with integral thermal-overload protection.
6. Low Ambient Kit: Permits operation down to 0 deg F
7. Mounting Base: Concrete pad, 4 inches nominal thickness, extend 6 inches beyond all sides of equipment

2.6 ACCESSORIES

A. Control equipment and sequence of operation are specified in Section 23 09 23 "Instrumentation and Control for HVAC.”

B. Thermostat: Control compressor and evaporator fan, with the following features:
   1. Compressor time delay.
   2. 24-hour time control of system stop and start.
   3. Liquid-crystal display indicating temperature, set-point temperature, time setting, operating mode, and fan speed.
   4. Fan-speed selection including auto setting.

C. Automatic-reset timer to prevent rapid cycling of compressor.

D. Liquid Line Filter Driers:
   1. Provide a sealed canister type liquid line filter drier with high water capacity for units with less than ten tons total cooling capacity. Provide a ball valve on each side.
   2. Provide a replaceable core type liquid line filter drier with high water capacity for units with ten tons total cooling capacity or greater. Provide a ball valve on each side.

E. Defrost Controls: A time initiated, temperature terminated defrost system shall ship with a setting of 70-minute cycle, with a choice of 50- or 90-minute cycle. Timed override limits defrost cycle to 10 minutes shall be available on units 10 tons and above. Adaptive demand defrost shall be provided on units below 10 Tons.

F. Electrical: Provide single point unit power connection.

G. Unit control box shall be located within the unit and shall contain controls for compressor, reversing valve and fan motor operation and shall have a 50 VA 24-volt control circuit transformer and a terminal block for low voltage field wiring connections.

H. Additional Monitoring:
   1. Monitor constant and variable motor loads.
   2. Monitor variable-frequency-drive operation.
   3. Monitor economizer cycle.
   4. Monitor cooling load.
   5. Monitor air distribution static pressure and ventilation air volumes.

2.7 CAPACITIES AND CHARACTERISTICS

A. Cooling Capacity: SEER - Minimum of 14.0. Refer to Drawings.

B. Heating Type: Electric or heat pump or none. Refer to Drawings.

C. Indoor Unit:
   1. Fan Motor Electrical Characteristics:
      a. Volts: Refer to Drawings.
      b. Phase: Refer to Drawings.

D. Outdoor Unit:
   1. Type: Air cooled.
   2. Electrical Characteristics:
      a. Volts: Refer to drawings
      b. Phase: Refer to drawings

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install units level and plumb.

B. Install evaporator-fan components using manufacturer's standard mounting devices securely fastened to or from building structure.

C. Install ground-mounted, compressor-condenser components on 4-inch- thick, reinforced concrete base that is 6 inches larger, on each side, than unit. Concrete, reinforcement, and formwork are specified in Section 03 30 00 "Cast-in-Place Concrete." Coordinate anchor installation with concrete base.

D. Install roof-mounted, compressor-condenser components on equipment supports specified in Section 07 72 00 "Roof Accessories." Anchor units to supports with removable, cadmium-plated fasteners.

E. Install and connect pre-charged refrigerant tubing to component's quick-connect fittings, locations allowing. After connecting to the manufacturer's quick connect fittings, transition within 12" to fabricated and installed tubing in accordance with the units' manufacturer's installation instructions and Section 23 23 00 – Refrigerant Piping.

F. The refrigeration system shall be installed and tested in accordance with the International Mechanical Code. Afterwards, the refrigerant system shall pass a standing vacuum test at 500 microns or manufacturer's requirements whichever is more stringent for a minimum of 12 hours.

G. Connection and removal of tubing or gages to a refrigerant charged assembly must be done by a Certified Refrigerant Technician. Adding or removing refrigerant to an assembly must be done by a Certified Refrigerant Technician.

H. Install refrigerant and condensate drainage tubing to allow access to unit.

I. Provide a complete set of new air filters for each unit at Substantial Completion.

3.2 CONNECTIONS

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where piping is installed adjacent to unit, allow space for service and maintenance of unit.

3.3 FIELD QUALITY CONTROL

A. Complete the manufacturer’s installation and startup checklists and resolve all discrepancies.

B. Provide the Commission Agent and Owner PM with the completed checklists/test results.

C. Perform tests and inspections.
   1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
   2. Tests and Inspections:
      a. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
      b. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
      c. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
   3. Remove and replace malfunctioning units and retest as specified above.
   4. Prepare test and inspection reports.

3.4 TRAINING

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

END OF SECTION

SECTION 23 81 46

WATER SOURCE UNITARY HEAT PUMPS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following types of water-source heat pumps:
   1. Concealed horizontal or vertical units.
   2. Rooftop units.

1.2 ACTION SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each model.

B. Field quality-control test reports.

C. 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.
   1. Wiring Diagrams: Power, signal, and control wiring.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality-control test reports.

B. Special warranties.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. ASHRAE Compliance:
   1. ASHRAE 15.
   2. Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
   3. Applicable requirements in ASHRAE/IESNA 90.1, Section 6 "Heating, Ventilating, and Air-Conditioning

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

C. Comply with NFPA 70.

D. Comply with safety requirements in UL 484 for assembly of free-delivery water-source heat pumps.

1.6 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace refrigeration components of water-source heat pumps that fail in materials or workmanship within five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 CONCEALED HORIZONTAL OR VERTICAL WATER SOURCE HEAT PUMPS

A. Approved Manufacturers:
1. Trane.
2. Aaon.
3. FHP Manufacturing, Inc. (BOSCH).
4. Daikin.

B. Description: Packaged water-source heat pump with temperature controls; factory assembled, tested, and rated according to ARI-ISO-13256-1.

C. Cabinet and Chassis: Galvanized-steel casing with the following features:
1. Access panel for access and maintenance of internal components.
2. Knockouts for electrical and piping connections.
3. Flanged duct connections.
4. Cabinet Insulation: Glass-fiber liner, minimum 1/2 inch thick, passing UL 181.
5. Condensate Drainage: Plastic or stainless-steel drain pan with condensate drain piping projecting through unit cabinet
6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
7. Sound Attenuation Package:
   a. Minimum 0.598-inch- thick compressor enclosure and front panel.
   b. Sound attenuating blanket over compressor.

D. Fan: Direct driven, centrifugal with multispeed motor resiliently mounted in fan inlet.
1. General requirements for motors are specified in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."

2. Blower shall have inlet rings to allow removal of wheel and motor from one side without removing housing. Units shall have a direct-drive centrifugal fan. The fan motor shall be constant CFM ECM motor. ECM variable speed ball bearing type motor. The ECM fan motor shall provide a soft low noise fan start by ramping fan up to full selected speed over a 30 second period, and slowly ramp down fan at the end of each blower cycle, maintain constant CFM, maximize motor efficiency over its static operating range, and provide airflow adjustment in multiple CFM increments.
3. The fan motor shall be isolated from the housing.
4. The motor shall be permanently lubricated and have thermal overload protection.
5. A dehumidification mode shall be provided to allow lower airflows in cooling for dehumidification.

E. Water Circuit:
1. Refrigerant-to-Water Heat Exchangers: Coaxial heat exchangers with copper water tube with enhanced heat-transfer surfaces inside a steel shell; both shell and tube leak tested to 450 psig on refrigerant side and 400 psig on water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators.
2. Motorized Water Valve: Stop water flow through the unit when compressor is off.

F. Refrigerant-to-Air Coils: Copper tubes with aluminum fins, leak tested to 450 psig.

G. Refrigerant Circuit Components:
1. Sealed Refrigerant Circuit: Charge with R-407C or R-410A refrigerant.
2. Charging Connections: Service fittings on suction and liquid for charging and testing.
3. Units shall contain a high efficiency scroll compressor designed for heat pump operation, a thermostatic expansion valve for refrigerant metering, an enhanced corrugated aluminum lanced fin and rifled copper tube refrigerant to air heat exchanger, reversing valve, coaxial tube in tube refrigerant to water heat exchanger, and safety controls including a high pressure switch, low pressure switch, water coil low temperature sensor, and air coil low temperature sensor.
4. Access fittings shall be factory installed on high and low pressure refrigerant lines to facilitate field service. Activation of safety device shall prevent compressor operation via a microprocessor lockout circuit. The lockout circuit shall be reset at the thermostat or at the contractor supplied disconnect switch.
5. Hermetic compressors shall be internally sprung. Compressor shall have thermal overload protection. Compressor shall be located in an insulated compartment away from air stream to minimize sound transmission.
6. Refrigerant to air heat exchangers shall utilize enhanced corrugated lanced aluminum fins and rifled copper tube construction rated to withstand 625 PSIG refrigerant working pressure.
   a. Refrigerant to water heat exchangers shall be of copper inner water tube and steel refrigerant outer tube design, rated to withstand 625 PSIG working refrigerant pressure and 500 PSIG working water pressure.

b. The refrigerant to water heat exchanger shall be “electro-coated” with a low cure cathodic epoxy material a minimum of 0.4 mils thick (0.4 – 1.5 mils range) on surfaces.
c. The coating shall provide a minimum of 1,000 hours salt spray protection per ASTM B117-97 on all external steel and copper tubing.
d. The material shall be formulated without the inclusion of heavy metals and shall exhibit a pencil hardness of 2H (ASTM D3363-92A), crosshatch adhesion of 4B-5B (ASTM D3359-95), and impact resistance of 160 in-lbs (184 kg-cm) direct (ASTM D2794-93).

7. Refrigerant metering shall be accomplished by thermostatic expansion valve. Expansion valves shall be dual port balanced types with external equalizer for optimum refrigerant metering. Units shall be designed and tested for operating ranges of entering water temperatures from 20° to 120°F.
8. Reversing valve shall be four-way solenoid activated refrigerant valve
9. Provide additional factory- installed safeties as follows:
   a. Antirecycle timer.
   b. Freezestat to stop compressor if water-loop temperature in refrigerant-to-water heat exchanger falls below 35 deg F
   c. Condensate overflow switch to stop compressor with high condensate level in condensate drain pan.
10. Refrigerant Piping Materials: ASTM B 743 copper tube with wrought-copper fittings and brazed joints.
11. Pipe Insulation: Refrigerant minimum 3/8-inch- thick, flexible elastomeric insulation on piping exposed to airflow through the unit. Maximum 25/50 flame-spread/smoke-development indexes according to ASTM E 84.

H. Electric Heating Coil: Helix-wound, nickel-chromium wire-heating elements in ceramic insulators mounted on steel supports. Energize on call for heating when entering- water-loop temperature is less than 60 deg F.

I. Filters: Disposable, pleated, 2 inch thick, with minimum efficiency reporting value MERV-13.

J. Electrical: Provide with fused disconnect and factory mounted controller. The controller shall be located within the unit compressor compartment and shall contain control transformer, compressor contactor, terminal block for thermostat wiring and solid-state controller for complete unit operation. The controller shall have a door to protect the internal components. Allow access to the components behind the controller box. Reversing valve and fan motor wiring shall be routed through the electronic controller. Units shall be name-plated for use with time delay fuses or HACR circuit breakers. Unit controls shall be 24 Volt and provide heating or cooling as required by the remote thermostat/sensor.

K. Units shall have a solid-state control system. The control system microprocessor board shall protect against building electrical system noise contamination, EMI, and RFI interference. The control system shall have the following features:
1. Anti-short cycle time delay on compressor operation.

2. Random start on power up mode.
3. Low voltage protection.
4. High voltage protection.
5. Unit shutdown on high or low refrigerant pressures.
6. Unit shutdown on low water temperature.
7. Condensate overflow electronic protection.
8. Option to reset unit at thermostat or disconnect.
9. Ability to defeat time delays for servicing.
10. Light emitting diode (LED) on circuit board to indicate high pressure, low pressure, low voltage, high voltage, low water/air temperature cut-out, condensate overflow, and control voltage status.
11. The low-pressure switch shall not be monitored for the first 120 seconds after a compressor start command to prevent nuisance safety trips.
12. 24V output to cycle a motorized water valve with compressor contactor.
13. Water coil low temperature sensing.
14. Air coil low temperature sensing.
15. Minimized reversing valve operation (Unit control logic shall only switch the reversing valve when cooling is demanded for the first time. The reversing valve shall be held in this position until the first call for heating, ensuring quiet operation and increased valve life.).
16. Emergency shutdown contacts.

L. Building Automation System Interface
   1. The control board will be supplied with BACnet MS/TP interface card. The following points must be available at a central or remote computer location:
      a. space temperature
      b. leaving water temperature
      c. discharge air temperature
      d. command of space temperature setpoint
      e. cooling status
      f. heating status
      g. low temperature sensor alarm
      h. low pressure sensor alarm
      i. high pressure switch alarm
      j. condensate overflow alarm
      k. hi/low voltage alarm
      l. fan “ON/AUTO” position of space thermostat as specified above
      m. unoccupied/occupied command
      n. cooling command
      o. heating command
      p. fan “ON/AUTO” command
      q. fault reset command
      r. itemized fault code revealing reason for specific shutdown fault
      s. Control voltage transformer.

2.2 ROOFTOP WATER SOURCE HEAT PUMPS

A. Approved Manufacturers:
   1. Trane.
   2. FHP Manufacturing, Inc. (BOSCH).
   3. Daikin.

B. Description: Packaged water-source heat pump with temperature controls; factory assembled, tested, and rated according to ARI-ISO-13256-1.

C. Cabinet and Chassis: Galvanized-steel casing with the following features:
   1. Water- and air-tight access panels for access and maintenance of internal components.
   2. Knockouts for electrical and piping connections.
   3. Flanged duct connections.
   4. Cabinet Insulation: Glass-fiber liner, minimum 1 inch thick, complying with UL 181.
   5. Condensate Drainage: Plastic or stainless steel drain pan with condensate drain piping projecting to unit exterior.
   6. Exterior Finish: Selected by Architect from manufacturer's standard colors.
   7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Fan: Direct driven, centrifugal with multispeed motor resiliently mounted in fan inlet.
   1. General requirements for motors are specified in Section 23 05 13 "Common Motor Requirements for HVAC Equipment."
   2. Blower shall have hinged access door to allow removal of wheel and motor from one side of unit. Units shall have a direct-drive centrifugal fan. The fan motor shall be constant CFM ECM motor. ECM variable speed ball bearing type motor. The ECM fan motor shall provide a soft low noise fan start by ramping fan up to full selected speed over a 30 second period, and slowly ramp down fan at the end of each blower cycle, maintain constant CFM, maximize motor efficiency over its static operating range, and provide airflow adjustment in multiple CFM increments.
   3. The fan motor shall be isolated from the housing.
   4. The motor shall be permanently lubricated and have thermal overload protection.
   5. A dehumidification mode shall be provided to allow lower airflows in cooling for dehumidification.

E. Water Circuit:
   1. Refrigerant-to-Water Heat Exchangers: Coaxial heat exchangers with copper water tube with enhanced heat-transfer surfaces inside a steel shell; both shell and tube leak tested to 450 psig on refrigerant side and 400 psig on water side. Factory mount heat exchanger in unit on resilient rubber vibration isolators.
   2. Motorized Water Valve: Stop water flow through the unit when compressor is off.

F. Refrigerant-to-Air Coils: Copper tubes with aluminum fins, leak tested to 450 psig.

G. Refrigerant Circuit Components:

1. Sealed Refrigerant Circuit: Charge with R-407C or R-410A refrigerant.
2. Charging Connections: Service fittings on suction and liquid for charging and testing.
3. Units shall contain a high efficiency two-stage scroll compressor designed for heat pump operation, a thermostatic expansion valve for refrigerant metering, an enhanced corrugated aluminum lanced fin and rifled copper tube refrigerant to air heat exchanger, reversing valve, coaxial tube in tube refrigerant to water heat exchanger, and safety controls including a high pressure switch, low pressure switch, water coil low temperature sensor, and air coil low temperature sensor.
4. Access fittings shall be factory installed on high and low pressure refrigerant lines to facilitate field service. Activation of safety device shall prevent compressor operation via a microprocessor lockout circuit. The lockout circuit shall be reset at the thermostat or at the contractor supplied disconnect switch.
5. Hermetic compressors shall be internally sprung. Compressor shall have thermal overload protection. Compressor shall be located in an insulated compartment away from air stream to minimize sound transmission.
6. Refrigerant to air heat exchangers shall utilize enhanced corrugated lanced aluminum fins and rifled copper tube construction rated to withstand 625 PSIG refrigerant working pressure. Refrigerant to water heat exchangers shall be of copper inner water tube and steel refrigerant outer tube design, rated to withstand 625 PSIG working refrigerant pressure and 500 PSIG working water pressure. The refrigerant to water heat exchanger shall be “electro-coated” with a low cure cathodic epoxy material a minimum of 0.4 mils thick (0.4 – 1.5 mils range) on surfaces. The coating shall provide a minimum of 1,000 hours salt spray protection per ASTM B117-97 on external steel and copper tubing. The material shall be formulated without the inclusion of heavy metals and shall exhibit a pencil hardness of 2H (ASTM D3363-92A), crosshatch adhesion of 4B-5B (ASTM D3359-95), and impact resistance of 160 in-lbs (184 kg-cm) direct (ASTM D2794-93).
7. Refrigerant metering shall be accomplished by thermostatic expansion valve. Expansion valves shall be dual port balanced types with external equalizer for optimum refrigerant metering. Units shall be designed and tested for operating ranges of entering water temperatures from 20° to 120°F.
8. Reversing valve shall be four-way solenoid activated refrigerant valve,
9. Provide additional factory- installed safeties as follows:
   a. Antirecycle timer.
   b. Freezestat to stop compressor if water-loop temperature in refrigerant-to-water heat exchanger falls below 35 deg F
   c. Condensate overflow switch to stop compressor with high condensate level in condensate drain pan.
10. Refrigerant Piping Materials: ASTM B 743 copper tube with wrought-copper fittings and brazed joints.
11. Pipe Insulation: Refrigerant minimum 3/8-inch- thick, flexible elastomeric insulation on piping exposed to airflow through the unit. Maximum 25/50 flame-spread/smoke-development indexes according to ASTM E 84.

H. Electric Heating Coil: Helix-wound, nickel-chromium wire-heating elements in ceramic insulators mounted on steel supports. Energize on call for heating when entering- water-loop temperature is less than 60 deg F.

I. Filters: Disposable, pleated, 2 inch thick, with minimum efficiency reporting value MERV-13.

J. Electrical: Provide with fused disconnect and factory mounted controller. Controller shall be located within the unit compressor compartment and shall contain control transformer, compressor contactor, terminal block for thermostat wiring and solid-state controller for complete unit operation. Controller shall have a door to protect the internal components. allow access to the components behind the controller box. Reversing valve and fan motor wiring shall be routed through the electronic controller. Units shall be name-plated for use with time delay fuses or HACR circuit breakers. Unit controls shall be 24 Volt and provide heating or cooling as required by the remote thermostat/sensor.

K. Outdoor-Air Damper: Linked damper blades, adjustable, with fully modulating, spring-return damper motor and hood.

L. Air-Side Economizer: Return-, relief-, and outdoor-air dampers with neoprene seals and with weather-resistant hood.
   1. Damper Motors: Fully modulating spring return with adjustable minimum position potentiometer.
   2. Temperature Control: Microprocessor-based controller using outdoor-air, mixed-air temperature and selects between outdoor-air and return-air enthalpy to adjust mixing dampers with water-loop entering temperature greater than 70 deg F. Delay opening outdoor-air damper to minimum position until room thermostat is satisfied at room set-point temperature.
   3. Relief Damper: Gravity-actuated damper with bird screen and hood.

M. Roof Curb: Steel, with corrosion-protection coating, gasketing, and factory-installed wood nailer; complying with NRCA standards; minimum height of 14 inches.

N. Units shall have a solid-state control system. The control system microprocessor board shall protect against building electrical system noise contamination, EMI, and RFI interference. The control system shall have the following features:
   1. Anti-short cycle time delay on compressor operation.
   2. Random start on power up mode.
   3. Low voltage protection.
   4. High voltage protection.
   5. Unit shutdown on high or low refrigerant pressures.
   6. Unit shutdown on low water temperature.
   7. Condensate overflow electronic protection.
   8. Option to reset unit at thermostat or disconnect.
   9. Ability to defeat time delays for servicing.

10. Light emitting diode (LED) on circuit board to indicate high pressure, low pressure, low voltage, high voltage, low water/air temperature cut-out, condensate overflow, and control voltage status.
11. The low-pressure switch shall not be monitored for the first 120 seconds after a compressor start command to prevent nuisance safety trips.
12. 24V output to cycle a motorized water valve with compressor contactor.
13. Water coil low temperature sensing.
14. Air coil low temperature sensing.
15. Minimized reversing valve operation (Unit control logic shall only switch the reversing valve when cooling is demanded for the first time. The reversing valve shall be held in this position until the first call for heating, ensuring quiet operation and increased valve life.).
16. Override temperature control with 2-hour timer for room occupant to override setback temperature at the thermostat.
17. Emergency shutdown contacts.

O. Building Automation System Interface
1. The control board will be supplied with BACnet MS/TP interface card. The following points must be available at a central or remote computer location:
a. space temperature
b. leaving water temperature
c. discharge air temperature
d. command of space temperature setpoint
e. cooling status
f. heating status
g. low temperature sensor alarm
h. low pressure sensor alarm
i. high pressure switch alarm
j. condensate overflow alarm
k. hi/low voltage alarm
l. fan “ON/AUTO” position of space thermostat as specified above
m. unoccupied/occupied command
n. cooling command
o. heating command
p. fan “ON/AUTO” command
q. fault reset command
r. itemized fault code revealing reason for specific shutdown fault
s. Control voltage transformer.

2.3 HOSE KITS

A. General: Hose kits shall be designed for minimum 400 psig working pressure, and operating temperatures from 33 to 211 deg F. Tag hose kits to equipment designations.

B. Hose: Hose material: braided stainless steel with adapters for pipe connections. Minimum diameter to be determined based on pressure drop of valves and fittings. Maximum pressure drop shall not be more than 10 psi.

1. Provide submittal with pressure drop calculations of valves and fittings at design flow for each unit. Minimum size shall be water-source heat-pump connection size.

C. Isolation Valves: Two-piece bronze-body ball valves with stainless-steel ball and stem and galvanized-steel lever handle. Provide valve for supply and return.

D. Strainer: Y-type with blowdown valve in supply connection.

E. Balancing Device: Mount in return connection. Include meter ports to allow flow measurement with differential pressure gage.
   1. Automatic balancing valve, factory set to operate within 10 percent of design flow rate over a 40:1 differential pressure range of 2 to 80 psig.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for piping and electric installations for water-source unitary heat pumps to verify actual locations of piping connections and electrical conduits before installation.

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

3.2 INSTALLATION

A. Equipment Mounting (ground mounted units):
   1. Install ground mounted water-source, unitary heat pumps on cast-in-place concrete equipment bases.
   2. Coordinate sizes and locations of concrete bases with actual equipment provided.
   3. Construct bases to withstand, without damage to equipment, seismic force required by code.
   4. Construct concrete bases 4 inches high and extend base not less than 6 inches in directions beyond the maximum dimensions of water-source heat pump unless otherwise indicated or unless required for seismic anchor support.
   5. Minimum Compressive Strength: 3000 psi at 28 days.
   6. 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 concrete base.
   7. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base, and anchor into structural concrete floor.
   8. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

9. Install anchor bolts to elevations required for proper attachment to supported equipment.

B. Suspend water-source, unitary heat pumps from structure with thread hanger rods and spring hangers. Minimum ¼” static deflection.

C. Equipment Mounting (Rooftop Units):
   1. Curb Support: Install roof curb on roof structure, level and secure, according to NRCA's "The NRCA Roofing and Waterproofing Manual,” current edition. Install and secure water-source heat pumps on curbs, and coordinate roof penetrations and flashing with roof construction. Secure units to curb support with anchor bolts as shown in the drawings.
   2. Unit Support: Install water-source heat pumps level on structural curbs. Coordinate wall penetrations and flashing with wall construction. Secure units to structural support with anchor bolts or as shown on Drawings.
   3. Isolation Curb Support: Install water-source heat pumps on isolation curbs, and install flexible duct connectors and vibration isolation and seismic-control devices.
   4. Comply with requirements in Division 23 Section 23 33 00 "Air Duct Accessories" for flexible duct connectors.
   5. Comply with requirements in Division 23 Section 23 05 48 "Vibration and Seismic Controls for HVAC Piping and Equipment" for vibration isolation and seismic-control devices.

D. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:
   1. Connect supply and return hydronic piping to heat pump as shown in the drawings.
   2. Connect heat-pump condensate drain pan to indirect waste connection with condensate trap of adequate depth to seal against the pressure of fan. Install cleanouts in piping at changes of direction.

E. Duct installation requirements are specified in other Sections.

F. Install piping adjacent to machine to allow service and maintenance.

G. Install wall-mounted temperature sensors and switch controls in electrical outlet boxes at heights to match lighting controls.

3.3 CONNECTIONS

A. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:
   1. Connect supply and return hydronic piping to heat pump with hose kits.

B. Install electrical devices furnished by manufacturer but not specified to be factory mounted.

C. Install piping adjacent to machine to allow space for service and maintenance.

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 field tests and inspections:
   1. After installing water to water heat pumps and after electrical circuitry has been energized, test units for compliance with requirements.
   2. Inspect for and remove shipping bolts, blocks, and tie-down straps.
   3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

C. Heat pumps will be considered defective if they do not pass tests and inspections.

D. Prepare test and inspection reports.

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. Inspect for visible damage to unit casing.
   3. Inspect for visible damage to compressor and coils.
   4. Inspect internal insulation.
   5. Verify that labels are clearly visible.
   6. Verify that clearances have been provided for servicing.
   7. Verify that controls are connected and operable.
   8. Adjust vibration isolators.
   9. Start unit according to manufacturer's written instructions.
   10. Complete startup sheets and attach copy with Contractor's startup report.
   11. Inspect and record performance of interlocks and protective devices; verify sequences.
   12. Operate unit for an initial period as recommended or required by manufacturer.
   13. Verify thermostat calibration.
   14. Inspect controls for correct sequencing of heating, refrigeration, and normal and emergency shutdown.

B. Complete the manufacturer’s installation and startup checklists and resolve all discrepancies.

C. Provide the Commission Agent and Owner with the completed checklists/test results.

3.6 ADJUSTING

A. Adjust initial temperature set points.

B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

3.7 TRAINING

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

END OF SECTION

SECTION 23 82 19

FAN-COIL UNITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:
   1. Fan-coil units
   2. Fan-coil unit accessories.

1.2 ACTION SUBMITTALS

A. Product Data: For each model indicated, provide dimensions, weights, capacities at scheduled conditions, required clearances, electrical requirements, components, and location and size of field connections.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 "Systems and Equipment" and Section 7 "Construction and Startup."

C. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6 "Heating, Ventilating, and Air-Conditioning."

1.6 COORDINATION

A. Coordinate layout and installation of fan coil units and suspension system components with other construction that penetrates or is supported by ceilings, including light fixtures, HVAC equipment, fire-suppression-system components, and partition assemblies.

B. Coordinate size and location of wall sleeves for outdoor-air intake.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. York International Corp.
   2. Daikin.
   3. Trane Company.
   4. JCI/York.

2.2 DUCTLESS FAN-COIL UNITS

A. Description: An assembly including cabinet, filter, chassis, coil, drain pan(s), fan, and motor. Factory-packaged and tested units rated according to ARI 440, ASHRAE 33, and UL 1995.

B. Coil Section Insulation: 1/2-inch thick, coated glass fiber complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916. Fire-Hazard Classification: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.

C. Main and Auxiliary Drain Pans: Composite Plastic or insulated stainless steel formed to slope from all directions to the drain connection as required by ASHRAE 62. Provide extended or auxiliary drain pan for piping connections.

D. Chassis: Galvanized steel where exposed to moisture. Floor-mounting units shall have leveling screws.

E. Cabinet: Steel with baked-enamel finish as scheduled.
   1. Panels: Removable, steel, with discharge grille and channel-formed edges, cam fasteners, and insulation on back of panel.
   2. Steel recessing flanges for recessing fan-coil units into ceiling or wall.

F. Filter Rack: Filter rack with access panel or door. Size filter rack to use two inch thick standard size filters at not more than 500 feet per minute face velocity.

G. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220ºF. Include manual air vent and drain valve.

H. Provide single-point electrical connection for heater and fan. Unit shall include control transformer and magnetic contactor.

I. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection.

1. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

J. Fan and Motor Board: Removable.
   1. Fan: Forward curved, double width, centrifugal; directly connected to motor. Thermoplastic or painted-steel wheels, and aluminum, painted-steel, or galvanized-steel fan scrolls.
   2. Motor: Permanently lubricated, multispeed; resiliently mounted on motor board. Comply with requirements in Division 23 Section 23 05 13 "Common Motor Requirements for HVAC Equipment."
   3. Wiring Termination: Connect motor to chassis wiring with plug connection.

K. Factory, Hydronic Piping Package: ASTM B 88, Type L copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet, and outlet.
   1. Hose Kits: Minimum 400-psig working pressure, and operating temperatures from 33 to 211ºF. Tag hose kits to equipment designations.
      a. Length: 24 inches.
      b. Minimum Diameter: Equal to fan-coil-unit connection size.
   2. Two-Piece Ball Valves: Bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig minimum CWP rating and blowout-proof stem.
   3. Calibrated-Orifice Balancing Valves: Bronze body, ball type; 125-psig working pressure, 250-deg F maximum operating temperature; with calibrated orifice or venturi, connections for portable differential pressure meter with integral seals, threaded ends, and equipped with a memory stop to retain set position.
   4. Y-Pattern Hydronic Strainers: Cast-iron body (ASTM A 126, Class B); 125-psig working pressure; with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum NPS 1/2 hose-end, full-port, ball-type blowdown valve in drain connection.
   5. Wrought-Copper Unions: ASME B16.22.

L. Control devices and operational sequences are specified in Division 23 Section 23 09 23 "Instrumentation and Controls for HVAC."

M. Basic Unit Controls:
   1. Control voltage transformer.
   2. Wall-mounting temperature sensor.
   3. Unoccupied-period-override push button.
   4. Data entry and access port.
      a. Input data includes room temperature set points and occupied and unoccupied periods.
      b. Output data includes room temperature, supply-air temperature, entering-water temperature, operating mode, and status.

2.3 DUCTED FAN-COIL UNITS

A. Configuration:

1. Horizontal Units: An assembly including cabinet, filter, chassis, coil, drain pan(s), fan, and motor in draw-through configuration with hydronic cooling coil and electric heating coil where specified.

B. Description: Factory-packaged and -tested units rated according to ARI 440, ASHRAE 33, and UL 1995.

C. Coil Section Insulation: 1-inch thick coated glass fiber complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.

1. Fire-Hazard Classification: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.

D. Drain Pans: Composite plastic or insulated stainless steel formed to slope from all directions to the drain connection as required by ASHRAE 62. Provide extended drain pan or auxiliary drain pan for piping connections.

E. Chassis: Galvanized steel where exposed to moisture, with baked-enamel finish and removable access panels.

F. Cabinets: Steel with galvanized or baked-enamel finish in manufacturer's standard paint color.

1. Supply-Air Plenum: Sheet metal plenum finished and insulated to match the chassis.
2. Return-Air Plenum: Sheet metal plenum finished to match the chassis.
3. Mixing Plenum: Sheet metal plenum finished and insulated to match the chassis with outdoor- and return-air, formed-steel dampers.

G. Dampers: Galvanized steel with extruded-vinyl blade seals, flexible-metal jamb seals, and interlocking linkage.

H. Filter Rack: Side access filter rack with access panel or door. Size filter rack to accept two inch thick standard size filters at not more than 500 feet per minute face velocity.

I. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220ºF. Include manual air vent and drain.

J. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection of heaters. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

K. Provide single-point electrical connection for heater and fan. Unit shall include control transformer and magnetic contactor.

L. Direct-Driven Fans: Double width, forward curved, centrifugal; with permanently lubricated, multispeed motor resiliently mounted in the fan inlet. Aluminum or painted-steel wheels, and painted-steel or galvanized-steel fan scrolls.

M. Belt-Driven Fans: Double width, forward curved, centrifugal; with permanently lubricated, single-speed motor installed on an adjustable fan base resiliently mounted in the cabinet. Aluminum or painted-steel wheels, and painted-steel or galvanized-steel fan scrolls.

N. Motors: Comply with requirements in Division 23 Section 23 05 13 "Common Motor Requirements for HVAC Equipment."

O. Factory, Hydronic Piping Package: ASTM B 88, Type L copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet, and outlet.

1. Hose Kits: Minimum 400-psig working pressure, and operating temperatures from 33 to 211ºF. Tag hose kits to equipment designations.
   a. Length: 24 inches.
   b. Minimum Diameter: Equal to fan-coil-unit connection size.
2. Two-Piece Ball Valves: Bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig minimum CWP rating and blowout-proof stem.
3. Calibrated-Orifice Balancing Valves: Bronze body, ball type; 125-psig working pressure, 250ºF maximum operating temperature; with calibrated orifice or venturi, connections for portable differential pressure meter with integral seals, threaded ends, and equipped with a memory stop to retain set position.
4. Y-Pattern Hydronic Strainers: Cast-iron body (ASTM A 126, Class B); 125-psig working pressure, with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum NPS 1/2 hose-end, full-port, ball-type blowdown valve in drain connection.
5. Wrought-Copper Unions: ASME B16.22.

P. Control devices and operational sequence are specified in Division 23 Section 23 09 23 "Instrumentation and Controls for HVAC."

Q. Basic Unit Controls:

1. Control voltage transformer.
2. Wall-mounting temperature sensor.
3. Unoccupied-period-override push button.
4. Data entry and access port.
   a. Input data includes room temperature set points and occupied and unoccupied periods.
   b. Output data includes room temperature, supply-air temperature, entering-water temperature, operating mode, and status.

PART 3 - EXECUTION

3.1 INSTALLATION

A. The fan coil units and associated components shall be installed in accordance with the manufacturer’s published installation instructions and their listings.

B. Install fan coil units level and plumb.

C. Install fan-coil units to comply with NFPA 90A.

D. Suspend fan-coil units from structure with elastomeric or spring isolation hangers. Vibration isolators are specified in Division 23 Section 23 05 48 "Vibration Controls for HVAC Piping and Equipment."

E. Verify locations of thermostats and other exposed control sensors with Drawings and room details before installation. Install devices 48 inches above finished floor unless noted otherwise.

F. Install new filters in each fan-coil unit within two weeks after Substantial Completion.

G. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:
1. Install piping adjacent to machine to allow service and maintenance.
2. Connect piping to fan-coil-unit factory hydronic piping package. Install piping package if shipped loose.
3. Connect condensate drain to indirect waste.
4. Install condensate trap of adequate depth to seal against the pressure of fan. Install cleanouts in piping at changes of direction.

H. Connect supply and return ducts to fan-coil units with flexible duct connectors specified in Division 23 Section 23 33 00 "Duct Accessories." Comply with safety requirements in UL 1995 for duct connections.

3.2 FIELD QUALITY CONTROL

A. The fan coil units and associated components shall be installed in accordance with the manufacturer’s installation instructions.

B. Perform the following field tests and inspections and prepare test reports:
1. Complete the pre-start up procedure and checklist included in the manufacturer’s installation instructions.
2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.

C. Remove and replace malfunctioning units and retest as specified above.

END OF SECTION